EAZA NUTRITION GROUP
&
ZOOLOGICKÁ ZAHRADA LIBEREC

ABSTRACT BOOK

Editors
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Liberecký kraj

Foreword

Dear friends and colleagues,

Time flies! After the first European Zoo Nutrition Conference in Rotterdam, in 1999, we are happy to present you the 9th European Zoo Nutrition Conference in Liberec, the Czech Republic.

The European Nutrition Group (ENG) has proven to be an active group within EAZA. Certainly, it means that the animals in the European zoos will benefit from the improved diets as a result of presentations, posters, workshops and discussions held at the conferences and by the other activities organised by the ENG. One of the promoters of the ENG, Andrea Fidgett, resigned after chairing the group for more than 10 years, as she accepted a position in the USA. Ollie Szyszka, nutritionist in Marwell Zoo, will be the new chair and intends to stimulate and promote zoo animal nutrition within the ENG and European zoo community.

The organising committee is pleased to present you a wide range of talks and posters, varying from sustainable palm oil, rhinoceros feeding, contraception by feeding, dietary drift, fertility in birds, milk composition, insects as feed for zoo animals to pest control in zoos.
Prior to the conference, the EAZA Academy in cooperation with ENG, organises a workshop on January 26th titled: pellet formulation. After the success of the practical workstations during the last conference in Arnhem Zoo, we will have several workstation again during the zoo visit on Saturday, where information will be presented on specific zoo animal nutrition items during.

We gratefully acknowledge financial support via sponsorship by Agro - Bio, Arie Blok Animal Nutrition, BAT Andrle, Format Solutions, Kiezebrink International, Marine Nutrition, Mazuri Zoo Foods, VVS Verměřovice, and Zooprofis. Their financial help and the products, supported the ENG and this conference. We kindly invite you to visit the booths, talk to the representatives, visit the websites and listen to the sponsor pitches. Many thanks also to the Liberec Regional Office for sponsoring this abstract book.

Preparing a conference takes a long time, a lot of discussions and emails. Many institutions and persons are involved: The organizing committee would like to thank the director of Zoologická Zahrada Liberec for hosting this conference dinner. Many thanks go to Petra Suchomelová and Petra Bolechová from Liberec Zoo for their fantastic help in organizing the conference and to Andrea Fidgett for the first steps in initiating this conference. Many thanks to the EAZA Executive office and especially to Mirko Marseille for coordinating the financial part of the conference, processing registrations as well as for regularly updating the conference website and taking responsibility of announcements. And many thanks to the organizing committee of this conference especially to Marcus Clauss for coordinating the programme and Geert Janssens end Annette Liesegang for organizing the workshop.

And finally we are pleased to welcome all participants. We hope you will enjoy the conference!

Anouk Fens, Apenheul Primate Park/VHL University of Applied Sciences
Joeke Nijboer, Nijboer Consultancy

Liberec, January 2017

Welcome everyone,

Thank you for attending the 9th biennial European Zoo Nutrition Conference. I do hope you enjoy the wonderful presentation and poster topics on offer and the chance to meet or catch-up with likeminded people.

I would like to take this opportunity to introduce myself as the new Chair of the EAZA Nutrition Group (ENG). I will be following in the footsteps of Dr. Andrea Fidgett, who this year took on a new challenge and has left some rather big shoes to fill. Andrea's knowledge of animal nutrition is exemplary and she can be immensely proud of her achievements with the ENG. She was a valued and well-respected Chair, and we would like to thank her for her leadership and to wish her the very best for her future endeavours.

My background is in Animal Science, focussing on livestock. I completed my PhD looking at sickness behaviour in cattle, and proceeded to work as a researcher on pig nutrition. This got me into animal nutrition and with past experience of working in a zoological collection as a keeper this allowed me to form a strong link between the two subjects and started working as an Animal Nutritionist at Marwell Zoo (UK) in 2014. Currently I am employed as the Animal Welfare Advisor, which includes both nutrition and welfare.

As the new Chair, I am grateful for the continuing and generous support of the committee members with their wealth of knowledge and experience. Furthermore, I will be supported closely in this role by Anouk Fens in particular, who will assist with the chairing duties which will allow us to share duties as well as additional communication on ideas and progress.
We relish the opportunity to make a difference and continue, and hopefully expand upon, the tasks already ongoing. This of course includes the organisation of these conferences as well as sourcing and distributing relevant materials, updating the website and liaising with different zoo nutrition experts across Europe to ensure good communications and collaborations. As the ENG sits within the research committee, it is a great opportunity to allow for additional result sharing and where possible joined research to fill some of the gaps in knowledge within zoo animal nutrition. This will of course reach beyond the ENG members and aims to form close links and communications between all interested professionals.

Once again, I wish everyone a successful conference and I hope to meet many of you in-person soon. As always, please remember to leave your feedback at the end so that we can seek to continually improve the event. We cannot do this without your input.

Best wishes,
Ollie Szyszka
(On maternity leave)

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Petra Bolechová, Zoo Liberec
Marcus Clauss, University of Zurich
Anouk Fens, VHL University of Applied Science/Apenheul Primate Park
Geert Janssens, University of Ghent
Annette Liesegang, University of Zurich
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Petra Suchomelová, Zoo Liberec
Ollie Szyszka, Marwell Zoo

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We wish to recognize and thank the following companies which have contributed to the success of the 9th European Zoo Nutrition Conference in Liberec:

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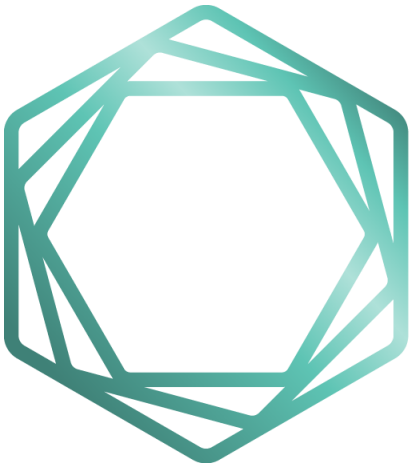

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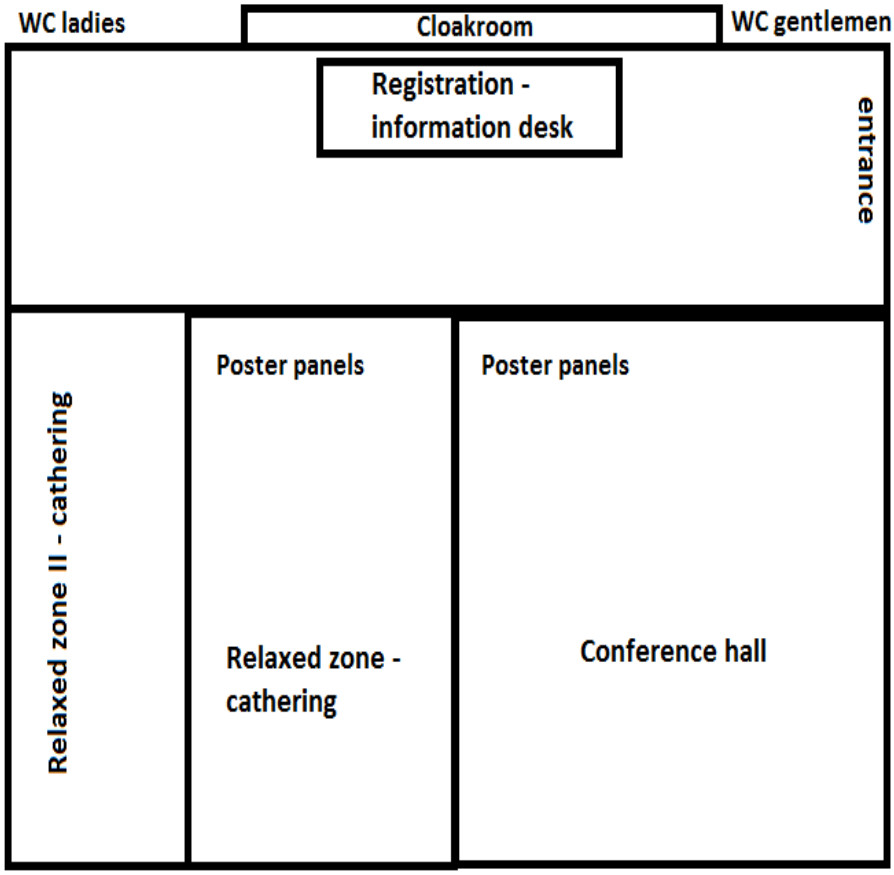

Local hosts

Petra Bolechová

Petra Suchomelová

Saturday 28th January – Zoo visit

Map of Liberec zoo and location of practical workstations

Conference programme

THURSDAY 26th January 2016

EAZA Workshop 2017 Pellet formulation and feeding

9:00 Opening

9.15 Feed formulation and feed technology – what is possible, what can be included in a pellet that it still will be a pellet? Dr. Kristina Johanssen

10:15 Break

10:30 Understanding nutritional declarations – EU laws – mistakes and wrong declarations. Which supplements are allowed (medication, antihelminthics, trace elements, vitamins) Prof. Josef Kamphues

11:30 Practical on different labels: reading a label correctly, what does it really tell us? (choosing commercially available pellets, differences) Prof. Annette Liesegang, Prof. Geert Janssens

12.15 Lunch Break

13 00 Safety issues and storage problems, spoiling due to mycotoxins, fungi? Dr. Joeke Nijboer, Dr. Tjalling Huisman

14:15 How to choose a pelleted product: Manufacturer portfolios, feeding instructions, product promotion and nutritional knowledge. Prof. Marcus Clauss

15:00 Break

15:15 Case reports

Developing pellets	Dr. Amy Powell
Developing a herbivore diet for Emmen Zoo	Prof. Marcus Clauss
Developing a black rhino diet for Zurich Zoo	Prof. Marcus Clauss
Case report on formulating milk for elephants	Dr. Angela Gimmel
Case report on working with local producers	Dr. Angela Gimmel
Developing Pellets for Parrots	Prof. Petra Wolf

16:15 Discussion

FRIDAY 27th January 2016 (page 2 – 17)

08.00 Registration

08.30 Welcome & Opening Remarks

09.00 Oil palm products in zoo animals feed: an underestimated ethical problem – Stanislav Lhota*

09.45 Gum-eaters: a review of the nutrition of exudativorous mammals – Francis Cabana*

10.15 Managing obesity in captive Lac Alaotra bamboo lemurs (*Hapalemur alaotrensis*) – Anouk Fens

10.30 The effects of probiotics in captive primates – Louise Cox

10.45 The use of maple leaves silage in nutrition of mantled guereza (*Colobus guereza*) – Olga Lasek

11.00 Break

11:30 Long-term health effects of great ape diets – Francis Cabana

12.00 Behavioural effects of fruit-free diets for primates – Anouk Fens

12:15 Let´s talk about browse, freeze, and palatability – Martine Verheij

12.30 More impacts of fruit-free diets for primates: New World primates at Shaldon Zoo – Amy Plowman

12:45 Influencing the frequency of regurgitation and reingestion by diet changes in orangutans (*Pongo spp.*) – Kristina Johansen

13.00 Lunch break & time for posters

14.15 Rhinoceros nutrition - reminder and update – Marcus Clauss

14.45 Visual body condition scoring in captive Asian (*Elephas maximus*) and African elephants (*Loxodonta africana*) – composite, algorithm and overview approaches – Christian Schiffmann

15:00 Pest control in zoos with emphasis on animal food – Joeke Nijboer

15.45 Break

16.15 An assessment of dietary drift and investigating why it occurs at Paignton Zoo Environmental Park – *Louise Cox*

16.30 "Too many cooks will spoil the broth": the advantages of a centralised nutrition centre in a zoo – *Cora Berndt*

17.00 Sponsor pitches

17.30 Format FAUNA™ - diet management software for healthy animals

18.00 Concluding Remarks

** Invited speaker*

SATURDAY 28th January 2016

(page 18 – 29)

08.00 Registration

08.30 Welcome and organisation for zoo visit

09.00 Zoo visit (including practical workstations)

12.30 Lunch break & time for posters

14.00 Can contraception in feed be used to manage captive giraffe populations? – *Andrea Fidgett*

14.15 Preliminary data on metabolic profile of okapis with glucosuria – *Sarah Depauw*

14.30 Effect of physical structure of concentrates in the diet on feed intake and feeding behaviour of nyala (*Tragelaphus angasii*) – *Marcin Przybyło*

14.45 Claw health and nutrition of Takin (*Budorcas taxicolor taxicolor*) – A case report from the nutritional services offered at the Institute of Animal Nutrition, Zurich – *Angela Gimmel*

15.00 Visitors feeding roughage to zoo herbivores – *Viktoria Michel*

15.15 Nutrition of Dendrohyrax species in Ostrava Zoo– *Jana Pluháčková*

15.30 Teeth and guts: Asian bear nutrition – *Francis Cabana**

15.45 Break

16.15 Nutrition and fertility in pet birds – *Petra Wolf*

16.30 Different nutritional requirements in the family Musophagidae (Turacos) – *Antonín Vaidl*

16.45 Basic data on nutrition in ostrich, rhea and emu – *Petra Wolf*

17.00 Birds of prey - nutrition and nutritional disorders – *Petra Wolf*

17.15 Microbial profiling in faeces of wild vs. captive cheetah fed meat or whole prey – *Anne Becker*

17.30 Scientific poster pitches

18:00 Conference Dinner – ZOO Liberec

** Invited speaker*

SUNDAY 29th January 2016

(page 30-40)

08.00 Registration

08.45 Welcome

09.00 Survey of feeding practices, body condition and faeces consistency in captive anti-eating mammals in the UK – *Marcus Clauss*

09.15 Asian pangolin nutrition: not what you might expect – *Francis Cabana**

09.30 Does chitin create a bias in crude protein analysis? – *An Cools*

09.45 Insects as feed for zoo animals – *Dennis Oonincx**

10.30 Break

11.00 Whole fish feeding in zoos - Nutrient analyses and losses during six month of storage – *Angela Gimmel*

11.15 Habitat selection, temperature ranges and implications for nutrition and body condition in a high Andean amphibian, the Titicana water frog – *Arturo Munóz*

11.30 Bone densities in three different populations of common spadefoots (*Pelobates fuscus*) by using computed tomography – *Martine van Zijl - Langhout*

11.45 Large-scale production of nutritious rotifers to enhance the reproductive capacities of ornamental fish – *Olivier Detournay*

12.00 Revising the diet of sea dragons (*Phycodurus eques*) to reduce mortality during relocation – *Kristina Johansen*

12.15 Micromineral tissue distributions across ornamental fish species – *Geert Janssens*

12.30 Concluding Remarks & Thanks

12.45 Lunch

** Invited speaker*

POSTER PRESENTATIONS

(page 42 – 64)

- Chemical composition of preys for insectivorous/carnivorous birds and reptiles - *Petra Wolf*
- Hygienic quality of feedstuffs for birds (from granivores to fish eaters) - *Petra Wolf*
- Poisonous plants for zoo animals - *Petra Wolf*
- Feedstuffs for carps and koi fish – a comparison with regard to nutrient composition and requirements - *Petra Wolf*
- Nutritional related obstipations in bearded dragons - *Petra Wolf*
- Investigation on feeding seed mixtures vs. extruded diets in parrots - *Petra Wolf*

ORAL PRESENTATIONS

Oil palm products in animal feed: an underestimated ethical problem

Stanislav Lhota

Ústí nad Labem Zoo, Czech Republic
Correspondence email: stanlhota.indo@gmail.com

Many zoos have recently started thinking out their own ecological footprint. Environmentally responsible and sustainable practices of the captive animal care are becoming a part of zoo conservation strategies. This includes, amongst other factors, environmentally responsible building, energy use, waste management, and animal feeding. However, this change often lags behind the conservation messages that the zoos pass on to the visitors and the wider public. Palm oil can be one such example.

Palm oil production represents the main cause of deforestation in Southeast Asia, and it is becoming a serious problem in tropical Africa and America, too. The ongoing expansion of palm oil plantations is threatening survival of charismatic animals such as orangutan, tigers, Asian elephants, clouded leopards, sun bears, as well as countless smaller and less known species. It is causing soil degradation and water pollution, thus affecting the economy of local communities as well.

Zoos were among the first institutions that exposed these serious issues to the broader public via campaigns that caused a huge international response. Today, many zoos continue advocating the boycott of palm oil, while others went for a more positive campaign supporting the sustainable production of palm oil and its certification according to the RSPO (Roundtable on Sustainable Palm Oil) Principles and Criteria. The zoos focus their campaign on the palm oil that is being used in human food and, to lesser extent, in cosmetics, house care products and biofuels.

However a significant proportion of palm oil, palm kernel oil and palm kernel meal is used to feed animals. This may include the zoo animals as well. Some products, such as the virgin red palm oil, which is used to supplement the diet of specialized parrots, may be available in sufficient supply in organic quality, and with RSPO certificates. However, the majority of the oil palm products used for animal feed is not RSPO certified and cannot be traced to the plantation. It is likely that these are not deforestation-free products. On the other hand, most of the oil palm products in zoo animal feed can be replaced by more sustainable non-tropical products. They are more widely available compared to the RSPO certified sustainably produced oil palm products traceable to plantation.

Given this situation on the market, avoiding oil palm products in zoo animal feed and replacing them with non-tropical alternatives is probably the most feasible, and immediately available solution.

KEYWORDS: environment, sustainability, ecosystem, deforestation, responsibility

Gum-eaters: a review of the nutrition of exudativorous mammals

Francis Cabana

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Gum is a widely available and composed mainly of soluble structural carbohydrates. No mammalian enzymes can digest gum; therefore a mammal ingesting gum must rely on microbial fermentation in order to access the energy it possesses. Gums are known as relatively nutrient poor. In spite of this, some mammals have evolved to exploit this food resource. I aim to review the literature for all mammal species which have been recorded to ingest gum, whether quantified or not, and discuss this in context of their evolutionary adaptations. I also investigated the recommended captive diets for these species to look at if gum is recommended. I conducted a literature search on ISI Web of Knowledge to tabulate all mammal species observed ingesting gum and classify them as obligate, facultative or opportunistic feeders. I encountered 92 mammal species that eat gum in the wild (26 obligate feeders, 35 facultative feeders and 31 opportunistic feeders). Obligate feeders have entirely evolved to exploit this resource but were found to not be given gum in captivity, which may explain why they are failing to thrive, as opposed to facultative feeders, which have fewer issues. Gum may be necessary for the health of obligate feeders in captivity, and I present data to this effect specifically for slow lorises (*Nycticebus* spp.), callitrichids (*Cebuella* and *Callithrix* spp.) and marsupial gliders (*Petaurids)*. Wasting syndromes, dental disease, cannibalism, abnormal behaviour patterns and dysbiosis of gut microbes have all been linked with inappropriate diets given to obligate gum feeders.

KEYWORDS: gummivory, exudativory, gum arabicum, fermentation

Managing obesity in captive Lac Alaotra bamboo lemurs (*Hapalemur alaotrensis*)

Anouk Fens[1]

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Corresponding email: a.fens@apenheul.nl

Since 1996, Lac Alaotra bamboo lemurs (*Hapalemur alaotrensis*) are classified as critically endangered and therefore managed within an EEP for several years. In captivity, high susceptibility to obesity is known in several lemur species, including bamboo lemurs. Obesity may cause health issues including diabetes and poor reproductive performance, and diets triggering obesity may be linked to dental diseases as well. Poor reproductive health may be reflected in disrupted hormonal cycles, macrosomia, etc.

This presentation will give an overview of the experiences in weight control in bamboo lemurs in Apenheul Primate Park over the last few years. In November 2014, our female died and the body weight (BW) of the male increased (from 1290 g to 1465 g). In the wild, Lac Alaotra bamboo lemurs have an average BW of 1240 g. Due to the increased BW, the diet was evaluated and changed. Fruit was removed and nutritional values were changed according to recommendations in literature. As a result, the male lost weight until a healthy BW was reached again.

In April 2016, two obese female bamboo lemurs arrived in Apenheul, weighing 2120 and 1510 g (being mother and daughter, respectively). Animals were successfully introduced. The diet was changed again, since animals spend a lot of time in the outside enclosure, having ad libitum access to fresh bamboo plants. In the next seven months, the older female lost almost 700 g. A similar trend was observed in the younger female; however, we suspected her to be pregnant. In September 2016 a healthy young was born, implicating the healthy status of the female.

Our experiences suggest that monitoring and weight management can have a positive effect on welfare and breeding results, and should be seriously considered when dealing with obesity in captive lemurs.

KEYWORDS: Primate nutrition, lemur, obesity

The effects of probiotics in captive primates

Louise Cox[1], Amy Plowman[2], Francis Cabana[3] & Brian Evans[1]

[1]Hartpury College, University of the west of England, United Kingdom; [2]Whitley Wildlife Conservation Trust, Paignton Zoo Environmental Park, United Kingdom; [3]Wildlife Reserves Singapore, Singapore Correspondence email: louise.cox@hartpury.ac.uk

Traditionally, antibiotics have been given to production animals to increase growth and improve overall health. However, due to the increase of antibiotic resistance and the EU ban on routine use of antibiotics, alternatives are sought. Probiotics are non-pathogenic, live bacteria which are voluntarily ingested to assist the gastrointestinal tract. There is an abundance of literature suggesting many health benefits for humans including reduction in frequency and duration of diarrhoea, reduction in frequency of infections and improved digestive health. However, some studies report no improvement of health particularly in older or critically ill patients. Similarly, many health benefits have been suggested in farm livestock and fish with the addition of probiotics to the diet including increased growth rates, increased immunity and lower mortality rates. Whilst the majority of literature is positive regarding probiotic benefits in livestock, some studies suggest probiotics have no positive effects at all, and could potentially worsen diarrhoea in horses. Little research has been conducted on zoo animals on the effectiveness of probiotics. Despite a lack of evidence, probiotics are often prescribed for non-domestic captive animals to treat diarrhoea and promote overall health.

This study investigates the effects of probiotics on the following 10 primate species at Paignton Zoo Environmental Park; bornean orangutan (n=1), grey gibbon (n=1), diana monkey (n=2), cherry crowned mangabey (n=4), goeldi monkey (n=5), emperor tamarin (n=3), king colobus (n=5), pygmy marmoset (n=5), red fronted lemur (n=2) and red ruffed lemur (n=2). Specifically, faecal score, food intake, and behaviour were assessed. In addition, apparent nutrient digestibility was also investigated on the two lemur species. Species were split into two groups of 5 species, with each group given a different probiotic in a double-blind study. One probiotic was a double strain containing *Enterococcus faecium and Saccharomyces cerevisiae*, the other a multistrain containing *Bacillus*, *Bifidobacterium*, *Lactobacillus* and *Streptococcus* strains. Probiotics were in a capsule form, and opened up scattered onto animals' normal diets. Pre-treatment observations were undertaken over 15 weeks starting in November 2015 with each species being studied every 5 weeks, creating 3 weeks of data per species. Probiotic treatment commenced in March 2016, with a 2 week acclimatization period, before a further 15 weeks of observations were completed.

No significant differences were found between food intake or behaviour before and during probiotics. Results showed a statistically significant increase in 'ideal' faecal scores and a significant reduction in 'bad' faecal scores when looking at all species overall. However, some species reacted differently, for example, goeldi monkeys and emperor tamarins had fewer ideal faecal scores. A significant difference between the effectiveness of the two probiotics was also discovered with the double strain probiotic showing more improvement in faecal scores than the multi strain. Apparent nutrient digestibility significantly improved for both lemur species during the probiotic phase. These results show probiotics could be beneficial for captive primates; however results cannot be generalised across all species and all probiotics.

The benefits from improved faecal scores and digestibility must be considered against the high cost of probiotics for regular use. It is also important to look at the underlying cause of diarrhoea and correcting this rather than merely controlling it using probiotics. Further research would be beneficial to assess effects in other primate species as well as other probiotics strains.

KEYWORDS: probiotics, primates, faecal score, behaviour, intake study, digestibility

The use of maple leaves silage in nutrition of mantled guereza (Colobus guereza)

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Young leaves are favored by mantled guereza, and the gastrointestinal tract of this species is well adapted to such a high fibre diet. In summer time, fresh maple leaves are often used in the diets for mantled guereza in captivity. The aim of the study was to optimize ensiling technology of the maple leaves as well as to determine chemical composition and fermentation parameters of maple leave silage, maple leave silage intake and digestibility. The experiment was carried out in the Silesian Zoological Garden (Chorzow, Poland). Maple leaves were ensiled in polyethylene 12 liters mikrosilos without additives (MLS), with a mixture of bacterial inoculants (MLS+BI) or with carrot additives (MLS+C; 10% on fresh feed basis). The containers with ensiled biomass were kept closed for 60 days (18 ± 2°C) prior to the digestibility trial. Basic nutrient, NDF, ADF, ADL and fermentation parameters (pH value, NH3-N, ethanol, organic acids) were determined by standard methods. The digestibility trial was carried out with group of seven mantled guereza, and digestibility was determined using an indicator method with acid insoluble ash used as marker. First, a diet without maple leaves silage (standard diet containing 223.8 g/kg DM crude protein, 85.2 g/kg DM crude fibre and 237.7 g/kg DM NDF) was fed. Thereafter, animals were shifted to a diet with maple leave silage (experimental diet; 20% of maple leaves silage without additives (MLS); as fed). Each diet was fed for 21 days, which included 7 days for diet adaptation and 14 for faecal collection. Silages contained 309, 275 and 254 g/kg of dry matter (DM), 171, 166 and 179 g of crude protein/kg DM and 367, 570 and 402 g of NDF/kg DM for MLS, MLS+BI and MLS+C, respectively. Maple leave silage with carrot additives was characterized by the best fermentation parameters (as indicated by pH and the content of lactic acids) and highest content of crude protein and true protein. Mantled guereza consumed on average of 3.48 kg/day of standard diet per group, whereas this intake increased to 3.62 kg/day when experimental diet was offered (4% increase). Therefore, higher nutrient intake (dry matter, protein, fat, fiber) and energy was observed when maple leave silage was included in the diet. Digestibility coefficients for all nutrients were higher for the diet with the addition of silage (78.4 vs. 64.4, 73.1 vs. 60.8, 78.3 vs. 64.7 for organic matter, crude protein and gross energy, respectively). In conclusion, maple leaves proved to be a good material for making silage. Furthermore, this study showed a possibility of applying maple leave silage in the diets for mantled guereza.

KEYWORDS: eastern black-and-white colobus, browse, digestibility, Old World monkey

Long-term health effects of great ape diets

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Chimpanzees (*Pan toglodytes)* and orangutans (*Pongo pymgaeus, albeii)* are described as frugivores. Chimpanzees ingest fruits all year long in varying proportions and orangutans ingest fruits for half the year (Sumatran), or unpredictably during masting seasons (Bornean). Sugar is a very important resource for Orangutans which lose up to half of their body weight during the lean seasons, and then gain it back during the fruiting season. Their physiology has evolved to seek out high energy foods such as fruits and to extract as much energy as possible, which is to be deposited as fat. A sustained high sugar intake in seasonal fruit eaters such as Orangutans or Gorillas (*Gorilla gorilla)* may lead to health issues such as obesity, diabetes, insulin resistance and heart disease, although these are also dependent upon physical activity. The repercussions of a constant high sugar diet for chimpanzees are expected to be less extreme than orangutans, although many health issues are still seen regularly in captivity.

In this project we transitioned Bornean and Sumatran orangutans and chimpanzees to a lower soluble carbohydrate diet and higher fibre diet to reflect natural feeding ecologies. Blood glucose values were taken from a subsample of orangutans and chimpanzees before and after the diet change as well as during the transition, coupled with intake studies and behavioural observations. Orangutans showed a very strong glucose control throughout the diet transition and lost weight even though the diet was isocaloric. They performed regurgitation and reingestion significantly less often and performed more socially affiliative behaviours. Chimpanzees had a less strict control of their blood glucose levels and did not lose a significant amount of weight on their new diets.

Results are representative of each species feeding ecologies' and have strong implications for the development of obesity, diabetes, and surprisingly, cardiac disease.

KEYWORDS: chimpanzee, orangutan, gorilla, fruits, frugivore, sugar, R/R, diabetes, behaviour

Behavioural effects of fruit-free diets for primates

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In captivity, many lemurs face health issues, including obesity, poor dental health, gastro-intestinal problems, as well as poor reproductive performance. Appropriate nutrition has shown to be important in prevention, since diets provided to lemurs in captivity vary considerably from their natural diets. Substitution of cultivated fruits for wild fruits leads to diets high in non-structural carbohydrates and low in fibre. Several studies indicated fruit-free diets being beneficial for physical health. Additionally, recent data showed a positive effect of fruit-free diets on behaviour in several lemur species. The aim of this study was to investigate behavioural effects of a fruit-free diet in ring-tailed lemurs in Apenheul Primate Park.

During a period of ten weeks, nine ring-tailed lemurs were observed in order to collect data on aggressive behaviour (ad libitum observations), self-directed behaviours (SDBs; focal animal sampling), and social relations (scan sampling). We examined the original diet (Diet A) consumed by the ring-tailed lemurs and compared with published recommendations in order to develop a fruit-free diet (Diet B), resembling the natural diet. The removal of fruit from the original diet resulted in increased fibre levels and lower levels of energy, fat and non-structural carbohydrate (primarily sugar). We found that the lemurs on the fruit-free diet showed less aggressive behaviour, however not being significant ($p>0.05$), and significantly more SDBs ($p=0.05$).

This is in contrast with a comparative study, in which both aggression and SDBs were significant lower in several lemur species when fed a fruit-free diet.

KEYWORDS: Lemur, fruit-free diet, non-structural carbohydrate, aggressive behaviour

Lets talk about, browse, freeze, and palatability

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Apenheul Primate Park (Apenheul) has specialized in keeping primates for over 40 years now. Apenheul currently keeps 37 different primate species, ranging from bonobo *(Pan paniscus)* to langurs (*Semnopithecus entellus, Trachypithecus auratus)*, from crowned sifakas (*Propithecus coronatus)* to callitrichids.
In 1976 the gorillas (*Gorilla gorilla gorilla)* arrived, being the first folivorous primate species in Apenheul, and from that time, feeding browse was initiated. Due to the arrival of more specialised folivorous primates such as black howler monkeys (1988/1989) (*Alouatta caraya)* and Javan langurs (1997) (*Trachypithecus auratus),* our knowledge and experience on feeding browse increased. At that time, browse was frozen and conserved for winter for the first time. After the arrival of the crowned sifakas (*Propithecus coronatus)*, we increased the diversity of frozen leaves. With the arrival of proboscis monkeys (*Nasalis larvatus)* in 2011, Apenheul faced an new challenge. These highly specialized folivorous primates require high quality browse of various species, both in summer and winter.
From that time on, data were recorded in order to determine the effect of the moment of harvesting and way of processing on intake rate and faecal consistency, in species such as red howler monkey *(Alouatta seniculus)*, crowned sifaka, langurs, and pudu *(Pudu Puda)*. With the years, the variety of browse species has increased, clearly influencing faecal consistency positively.
Over time, different freezing techniques have been tested on more than 30 leaf species, leading to different results. We have tested the suitability of different types of browse for freezing by recording visual aspects and acceptance after thawing. All primates have a preference for young leaves, but these are more difficult to thaw. They are very sensitive for wilting and pulverizing, and they effloresce after thawing. We developed a method where we seal the leaves while they stay on the branch and freeze them at -19°C. When we then thaw them later, most leaves keep their original consistency. The influence of wilting and decoloring of the leaves on acceptance differ. After thawing, for example, leaves of apple trees (Malus) become slack and brown but are very well accepted. When leaves of beech (Fagus) are thawed, they are indistinguishable from fresh leaves but apparently less tasteful and acceptance is minimal.
Our knowledge and experience in feeding a variety of browse all year round has contributed to animal welfare by stimulating natural feeding behaviour and providing high quality diets.

KEYWORDS: primate nutrition, frozen browse, folivore, freezing and thawing method

More impacts of fruit-free diets for primates: New World primates at Shaldon Zoo

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Since the European Zoo Nutrition Conference in 2012 we have been reporting on the beneficial effects of removing fruit from the diets of zoo primates. We have replaced fruit with vegetables (predominantly green, leafy varieties), invertebrates and/or gum, depending on primate species, and changed pellets to types with higher fibre concentrations. These changes reduce the concentration of readily digestible carbohydrate and increase protein and fibre levels in the diets. The benefits we have previously reported include improved dental health, better weight management, improved faecal consistency and reduced aggression and self-directed behaviour across a range of species. Some species have also shown increased foraging and feeding time and reduced abnormal or stereotypic behaviour.

In this presentation we report on the effects of similar diet changes on behaviour, faecal consistency and body condition scores for four species of New World primates at Shaldon Zoo: yellow-breasted capuchins *Cebus xanthosternos* and squirrel monkeys *Saimiri sciureus* housed as single species and pygmy marmosets *Cebuella pygmaea* housed together with a single golden lion tamarin *Leontopithecus rosalia.* There were some short term changes in behaviour during the transition period between the diets but in the long term the diet change resulted in few significant changes in behaviour. Time spent in locomotion significantly increased in all groups (Wald's $\chi^2 = 5.73$, $p = 0.02$) and Head Twist (possible stereotypy) significantly decreased in capuchins and squirrel monkeys (Wald's $\chi^2 = 7.89$, $p = 0.02$, it was not seen at all in the Callitrichids). Aggression and self-directed behaviour also decreased in all groups but not significantly so. Faecal consistency improved overall from 62.5% to 70.8% having an ideal score. Of the 17 individuals, nine showed no change in body condition and had an ideal score of 3 throughout, five gained condition and moved from a below ideal score (2 or 2.5) to ideal, one moved from below ideal (2) to above ideal (4) and two moved from ideal to just over ideal (3.5).

In addition to the Shaldon study we have also examined Paignton Zoo ZIMS records for all keeper notes of loose faeces and diarrhoea for four Callitrichid species and pygmy slow lorises before and after we implemented the fruit-free diets. In all five species frequency of loose faeces or diarrhoea was significantly reduced following the removal of fruit from their diets.

These results all support our previous findings that diets containing more fibre and less readily digestible carbohydrate (achieved by removing fruit) have beneficial effects on physical health and behaviour of zoo primates.

KEYWORDS: Primates, fruit-free diet, behaviour, faecal score, body condition

Influencing the frequency of regurgitation and reingestion by diet changes in orangutans (*Pongo* spp.)

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Regurgitation and re-ingestion (R/R) is considered an abnormal behavioural pattern seen in several species of primates in captivity. In a survey of orangutans within North American zoos, R/R was observed in 18% of the Sumatra orangutans and 45% of the Borneo orangutans included in the survey. Studies within various primate species have linked the behaviour with diet composition and foraging time. R/R has successfully been reduced in some of these cases by increasing the amount of forage accessible, such as providing ad libitum browse, decreasing the amount of fruit in the diet, increasing the amount of fibre and decreasing the time between feeds. These diet changes are all linked together. For example, increasing the amount of browse both increases foraging time and activity levels, decreases intervals between feedings and increases the amount of fibre in the diet. Studies in the wild indicate that orangutans have an ability to gorge when food is plentiful and efficiently store fat for times when food is less abundant. They select for sweet food items when given a choice. Orangutans in zoos are often presented with a diet relatively high in energy and low in fibre all year round, without the challenges associated with foraging in the wild.
In a group of four orangutans in Kristiansand Zoo, R/R was observed in two animals. In a group of three orangutans at Furuvik Zoo, R/R was seen in the two females. The diet in both groups was revised by removing almost all fruit and boiled vegetables from the diet, and by increasing the amount of browse, raw vegetables and greens. Feeding times were changed to reduce intervals between feedings. Keeper engagement and adherence to the revised nutritional programme was considered a crucial factor for the successful implementation of the diet changes. The keepers received further training on zoo animal nutrition in general and orangutan nutrition in detail and they were involved in the decision making process. The preliminary results indicate that the frequency of R/R has been reduced in both zoos, and the orangutans are perceived to be more active by the keepers.

KEYWORDS: orangutan, regurgitation and reingestion, fibre diet, fruit reduction

Rhinoceros nutrition - reminder and update

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The main three rhinoceros species kept in zoos differ in feeding type, with black rhinos (*Diceros bicornis*) strict browsrs, white rhinos (*Ceratotherium simum*) strict grazers, and greater one-horned rhinos (*Rhinoceros unicornis*) intermediate feeders with a strong tendency towards grazing. For all three species, forage-based diets are strongly recommended. For black rhino, to avoid excessive tooth wear, grass-based forages should only be used sparingly. Putting a management focus on the acquisition of quality forages is important for zoos keeping rhinos. In most situations, there is no need to feed fruit or grain-based products, and complete (pelleted) feeds used should contain high levels of fibre.

Obesity is of concern in all rhino species, and body condition scores have been developed for each of the three species that facilitate a consistent monitoring of body condition in the absence of the opportunity to weigh animals regularly. There is limited literature evidence that obesity might be associated with low reproductive success in black rhino, or with reproductive disease in greater one-horned rhino.

Although it has been known for a long time that black rhinos are susceptible to iron storage disease, i.e. excessive iron deposits at necropsy in various body tissues (especially the liver), the relevance of this condition appears to have been downplayed in Europe recently. However, a review of the literature clearly suggests that iron storage disease occurs in Europe as well as in North America. Therefore, limiting iron in diets of black rhinos is imperative (although difficult to achieve), and efforts to achieve this should be documented. Because the etiology of iron storage disease in black rhinos is still uncertain, and because phlebotomy is currently the only available treatment, it cannot be considered responsible to keep black rhinos without medical training that allows taking blood from unrestrained, conscious animals (both for obtaining blood samples that may help to elucidate causes of this and other unresolved health issues peculiar to black rhinos, and to facilitate the removel of iron from their bodies via phlebotomy).

KEYWORDS: rhinoceros, grazer, browser, forage, iron storage disease, training

Visual body condition scoring in captive Asian (*Elephas maximus*) and African elephants (*Loxodonta africana*) – composite, algorithm and overview approaches

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Various body condition scoring (BCS) methods have been developed as management tools in zoo animal husbandry. In contrast to BCS for farm animals where visual and palpable features are used, these protocols are mainly restricted to visual cues. Considering their inherent subjectivity, such methods face scepticism as their reliability is questioned. In terms of their respective methodology, composite BCS (where individual body regions are scored and a sum or mean is calculated), algorithm BCS (where a score is achieved by following a flow chart) and overview BCS protocols (where a score is given based on overall appearance) can be distinguished. In order to compare their practicability and consistency, we conducted a test with veterinary students (n=18) scoring an equal number (n=15 each) of African (*Loxodonta africana*) and Asian elephant (*Elephas maximus*) photographs using three different protocols. The composite approach showed least inter-observer consistency, while the overview protocol led to the highest differentiation of individual elephant conditions. When regularly assessed, visual body condition scoring may serve as an important tool for the health surveillance and complete the medical history of individual zoo elephants. Nonetheless, a validation process of each developed protocol should be performed before its application. Beside this, further research might concentrate on the long-term, individual-based body condition monitoring, using archives of standardized photographs.

KEYWORDS: Body condition scoring (BCS), weight monitoring, zoo animal, elephant

Pest control in zoos with emphasis on animal food

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A considerable amount of zoo animal food is spoiled by pests during storage, preparation, transport to facilities and in the zoo animal exhibits. The spoilage of the food consists contamination with diseases, damaging of the food, contamination with urine or faeces, and the eating of the food. No information is available on this subject; however it probably represents a minimum of 5% of the original amount.
Pest control should never be underestimated. It is not only a problem in zoos but a general problem, and much money is spend in the pest control industry all over the world. For example, 40.000 persons are working in the EU on pest control which costs about 3.000 million Euros annually!
This presentation shows the main pests in zoos and their life cycle. The main pests are brown and black rats, mice, German-, American, Australian and Oriental cockroaches, several fly species, (tropical) ants and stock damaging insects and birds.
In order to control pests a strategy called Integrated Pest Management (IPM) is recommended. This means that the use of biocides is only a part of the measurements to control pests. Prevention measurements have to be set up so pests cannot live, eat, shelter and breed in unwanted areas in zoos. For example, prevention measurements must be made in the foods storage area and feeding places. Special attention is needed in the so-called “natural” exhibits with high temperature and humidity, plants and cracks in the artificial stones. These environments are ideal for pests. Attention should also be paid to the internal and external transport system of food.
Used biocidal products are regulated by the Biocidal Products Regulation (BPR, EU 528/2012). An overview of the commonly used products will be presented. Items which will be discussed are lethal dose, persistency, resistance, environmental effects and secondary poisoning of several commonly used products. Additionally, examples of modern computer-monitored trapping system will be presented.

KEYWORDS: Integrated Pest Management, biocides, secondary poisoning, environmental effects

An assessment of dietary drift and investigating why it occurs at Paignton Zoo Environmental Park

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Dietary drift, where the diet an animal is fed differs to that specified on the diet sheet, is a widespread issue in many captive animal settings. Specific diets are created by nutritionists, vets, curators or senior keepers based on what is deemed to be best for the animal in a particular situation. However, what the animal is actually given (and what the animal chooses to eat from a given diet) can be very different in terms of nutritional content. Drift can happen for many reasons; swapping a non-available ingredient for a different one, feeding by number of an ingredient rather than weight of an ingredient, giving extra, e.g. finishing a box of ingredients rather than leaving a little in the box for next day, and giving extra food for enrichment or training. Whilst it may be necessary to give highly palatable (e.g. energy dense or sugary) reward items for training, these items are often not recorded thus allowing drift, particularly when keepers rotate sections meaning the same animals receive 'treats' on a regular basis. Drift can also happen accidentally, for instance when measuring food using a scoop or tub which may not accurately scoop the correct weight of food. When dietary drift occurs regularly, it can lead to unexplained weight changes in an animal and contribute to health issues associated with incorrect weight.

This study was conducted with the aim of evaluating nutritional differences between diet sheets, actual diets fed and diets eaten by the animals and investigating reasons why drift may occur. A 10 day intake study was conducted across 6 species at Paignton Zoo Environmental Park. Species from 3 sections (birds, primates and large mammals) were studied to determine whether diet preparation methods vary across the zoo. Diets were weighed before feeding and any leftovers weighed the following morning when taken out during cleaning. Offered diets and diets eaten were compared with diet sheet data and analysed on Zootrition computer software. Face to face semi-structured interviews were conducted with keepers (n=7) and food preparation volunteers (n=6).

Interviews found most keepers and volunteers making feeds followed some form of a diet sheet every day, however 2 keepers admitted to never looking at the full diet sheet, and 3 more only looked if they were on a new section or if there was a change in group number. Despite this, keepers generally said the full diet sheet was "good" and "clear" to read. Feeding in number of items showed a large amount of drift, for example, the red river hog diet included 12 beetroot which ranged in weight from 1527g to 3587g. Similarly, the weight of 4 mice for the Ural owls ranged between 91g to 133g. However, weighing ingredients did not solve this, with mandrills given 50.9% extra root vegetables and 22% extra pellet on one occasion, resulting in an extra 19% energy given than suggested on the diet sheet. From the 4 primate keepers interviewed, when asked if the mandrill diet was sufficient, 3 suggested the diet quantity was too small. This disagreement with the diet sheet could be a reason for more food being given, on average. However, 1 keeper understood the small amount, saying it "makes sense" after attending a training workshop, highlighting the importance of nutritional training. This was reinforced by a second keeper who suggested training would be "worthwhile".

Recommendations for preventing drift include random spot checks and specific nutritional training for keepers. Guidelines regarding the use of food for medication and training, and what to do when items are unavailable could also be beneficial. Two diet sheets may also help; a basic day-to-day sheet alongside a detailed reference sheet that includes nutritional information, feeding behaviours, date of review and suitable browse species.

KEYWORDS: dietary drift, intake study, interviews, mixed species

“Too many cooks will spoil the broth”: the advantages of a centralised nutrition centre in a zoo.

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The first centralized kitchen in the Netherlands was realized in Emmen Zoo in 1985. The advantages were huge: work is more efficient if you use fewer people to do the work! Many people from all over the world visited Emmen to experience the functionality of the kitchen.
The new zoo in Emmen, Wildlands Adventure Zoo Emmen, used the more than 30 years of experience to build an even better centralized animal nutrition centre which opened in January 2016. Improvements were made concerning location in the zoo, accessibility, transport possibilities, kitchen layout and sustainability. At the same time at Apenheul Primate Park, a nutrition centre was built. Their centralized kitchen opened in July 2015, and with the same purpose. More efficiency and effectiveness: the clear advantages of a centralized system.
A centralized system results in more efficiency in the use of time, in relation to purchase of products, managing costs (less ‘leftovers’), improvement of hygiene, pest control, diet and nutrition control, fewer but more experienced staff in the kitchen: more professionalism.
The presentation at this EAZA nutrition conference will discuss possibilities for architecture, layout, necessities (like computers, software, kitchen designs (interiors and furniture) etc.).
In 1985, the keepers at Emmen Zoo were initially resistant to the idea to give part of their job away: preparing food is considered one of the specific tasks of keepers. However, in time they got used to this situation and learned to appreciate its advantages. Good communication between keepers, kitchen staff members, nutritionists/veterinarians is essential to make this way of working a pleasant and advantageous success.

KEYWORDS: centralized animal nutrition centre, advantages, architecture, location, kitchen layout, logistics, accessibility, managing costs & hygiene & diet control

Can contraception in feed be used to manage captive giraffe populations?

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Careful breeding management helps to ensure genetically diverse captive wildlife populations. For many species, a set of breeding recommendations are given by a studbook keeper. Across regions and institutions, different management strategies are employed to follow these breeding recommendations, such as physically separating sexes, permanently or reversibly contracepting animals or allowing breeding to cull.
One type of reversible contraception used is Regu-mate® Porcine 0.4% w/v oral solution (altrenogest), a synthetic progestin which mimics the action of natural progesterone, inhibiting oestrus and ovulation. Regu-mate® Porcine is commonly used in equids and swine to regulate cyclicity and to improve breeding success in gilts. In exotic species, Regu-mate® Porcine has successfully been used to contracept a variety of marine mammals (including cetaceans and pinnipeds), and a number of ungulate species.
Information on global experiences with the application of contraception in exotic animal species is compiled by the EAZA Group on Zoo Animal Contraception within EAZA collections, and by the AZA Reproductive Management Center in the rest of the world. This information is curated in a centralised database of over 37,000 records however; to date little information has been collected on the application of Regu-mate® Porcine in giraffes.
The efficacy of Regu-mate® Porcine in giraffes was first demonstrated in one cow by using it as a daily topdressing on a small portion of pellets (dose ~ 0.047 mg/kg BM; slightly above recommended dose for horses) and observing the complete suppression of oestrous cycles (using faecal progesterone analysis) over 11 weeks (covering >4 oestrus cycles). The challenge with keepers handling Regu-mate® Porcine on a daily basis is that it is easily absorbed through the skin and it is highly advised that precautions are taken when handling the product; especially for female keepers. Therefore, Regu-mate® Porcine (dose: 16 mg/kg of feed) was milled into a batch of feed (HJ Lea Oaks, Aston, United Kingdom) of which the giraffe needed to consume at least 1.6 kg to meet the expected effective dose. Following a 3 week transition period onto the feed, sporadic behavioural signs of oestrus and frequent erratic elevations of faecal progesterone concentrations were seen; therefore, the decision was made to double the dose in the contracepted feed (to 32 mg/kg of feed). Immediately after changing to this increased dose, faecal progesterone concentrations fell and remained more consistently at baseline for 8 weeks (at the time of submitting this abstract).
The long-term efficacy of Regu-mate® Porcine in giraffes still needs to be documented, but milling it into feed appears to be a promising way of contracepting female giraffes with a much reduced risk for the keeping staff and without the need to regularly dart individuals with a concentrated product. The intention is to test the contracepted feed in another two female giraffes in the collection going forward.

KEYWORDS: Giraffe, formulated feed, contraception, Regu-mate® Porcine

Preliminary data on metabolic profile of okapis with glucosuria

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Currently, it is recognized that glucosuria in captive okapis is a worldwide phenomenon. Urine sampling of okapis from the Epulu Okapi Reserve in the Democratic Republic of Congo excluded the presence of glucosuria in the wild, thereby indicating captive management factors to be the cause. Although there is a general belief that feeding mismanagement of this strict browser causes glucosuria, the phenomenon still remains unexplained. Moreover, a drastic decrease in sugar and starch content in the diet did not reduce glucosuria in 4 adult captive okapis. However, this diet still contained considerable amounts of highly fermentable fiber, in contrast to browse. Rumen acidosis and laminitis occur within the captive browsing ruminant population, which are both induced by gut fermentation imbalances caused by highly fermentable carbohydrates.

We hypothesize that glucosuria in the captive okapi is also linked to imbalances in foregut fermentation processes.

Frozen urine samples (10) from 4 glucosuric okapis of Antwerp Zoo were available, with samples from different life stages per animal. From 1 okapi, urine samples before the onset of glucosuria were also present. Samples were analyzed for glucose, free amino acid and acylcarnitine content. Acylcarnitines are a reflection of the corresponding acyl coenzyme A compounds, that indicate the way and extent nutrients are used for energy. Despite difference in life stage or severity of glucosuria, urinary glucose concentrations were positively correlated with metabolites derived from gut fermentation processes (acetylcarnitine ($r=0.976$; $P<0.001$), propionylcarnitine ($r=0.848$; $P<0.001$)). Although this might be a first indication for the link between glucosuria and fermentation, this requires further assessment, since these metabolites can, at least partly, also originate from other metabolic processes. Furthermore, the results suggest that the glucose metabolism is not the only problem in these animals, since multiple positive correlations were found between urinary glucose concentrations and free amino acids (e.g. valine, $r=0.979= 0.96$; $P<0.001$; leucine, $r=0.978$; $P<0.001$). The lack of creatinine measurements implies that certain correlations may only exist because of dilution effects. Therefore, also metabolite ratios were tested, since ratios are independent of dilution. Several metabolite ratios were also tightly correlated with glucose concentration: for instance propionylcarnitine:acetylcarnitine positively correlated with glucose ($r=0.666$; $P=0.009$) suggesting a shift to a higher ruminal propionate:acetate ratio. Captive okapis suffering from glucosuria thus show an altered metabolic profile in the urine that can help explain the phenomenon. The profile indicates that it is therefore still worthwhile exploring more browse-based diets for okapis in the prevention of glucosuria.

KEYWORDS: Okapi, glucosuria, fermentation

Effect of physical structure of concentrates in the diet on feed intake and feeding behaviour of nyala (*Tragelaphus angasii*)

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Although not recommended, concentrate intake often exceeds 50% of dry matter (DM) ingested by wild captive ruminants, especially concentrate selectors and mixed feeders. Therefore physical structure of concentrates may have significant impact on feed intake, eating behaviour and rumination, and in consequence welfare and health of this group of ruminants in zoological gardens. The aim of the study was to determine the effect of physical structure of concentrates used in the diet for nyala antelope (*Tragelaphus angasii*) on feed intake and feeding behaviour, including eating time (min/d; min/n), frequency (n/d), rate (g DM/min), and rumination time (min/d; min/n; min/g DM) and frequency (n/d). The experiment was conducted according to Latin square design (4 x 4) on four adult males of nyala in Silesian Zoological Garden (Chorzów, Poland). Animals were fed a typical diet used for nyala in Silesia Zoological Garden that consisted of basal diet (a mixture of concentrates, vegetables and fruits) fed at 0.75 kg/day/animal, 0.5 kg/day/animal of chopped dehydrated lucerne (as fed) with additional *ad libitum* access to grass hay. Dietary treatments were: 1) ground concentrate mixture; 2) steam flaked concentrate mixture; 3) 6 mm diameter size pelleted concentrate mixture; 4) 12 mm diameter size pelleted concentrate mixture. Feed intake and rumination characteristics (number of bouts and time) were not statistically different between diets ($P > 0.05$). 6 mm pelleted concentrates resulted in shorter time ($P < 0.01$) and higher rate ($P = 0.01$) of basal diet intake, as compared to ground concentrates, and 12 mm diameter of pelleted feed increased time ($P = 0.05$) of basal diet intake. Steam flaked concentrates resulted in shorter time ($P < 0.01$) and higher rate ($P = 0.03$) of basal diet intake, as compared to ground concentrates. Eating time, frequency and rate of structured feeds (hay and chopped dehydrated lucerne) were not affected ($P > 0.05$) by physical structure of concentrates. Physical structure of concentrates affects feeding behaviour and thus may affect welfare of nyala and possibly other wild captive ruminants.

KEYWORDS: pellet, muesli, meal, zoo, ruminant

Claw health and nutrition of Takin (*Budorcas taxicolor taxicolor*) – A case report from the nutritional services offered at the Institute of Animal Nutrition, Zurich

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The feeding of herbivores in zoos often represents a challenge, especially when rare species from different climate zones are involved. The takin, which belongs to the subfamily of the goat-antelopes (*Caprinae*), is native to India, Myanmar and the People's Republic of China and lives at altitudes between 1,000 and 4,500 m above sea level. Takins are browsers, although depending on seasonal availability, they also consume fresh herbs and grass.
In the Tiergarten Nuremberg, problems with claw health were observed in the ram, after the group came to Nuremberg from another zoo, where the problems did not occur. Thus, the case was submitted to the nutritional consultation service of the Institute of Animal Nutrition, Vetsuisse Faculty, University of Zurich.
Reasons for reduced claw health in ruminants are numerous. In the literature, diets with high starch or high sugar contents increase the risk of lameness via ruminal acidosis. This problem is exacerbated when not enough roughage or browse are offered. Also, high protein diets are discussed to induce lameness in cattle. Regarding other dietary components, copper and zinc deficiency negatively impacts claw health in dairy herds.
In the Tiergarten Nuremberg, the takins are kept in an enclosure with different padding. A big part is dirt or grass paddock, with a small paved area, where the daily ration is offered. The daily ration in summer consists of fresh grass, second cut hay, carrots, beetroot, wheat bran, oats, pellets, vitamin and mineral supplements and crisp bread (used only for training). The whole group is fed together. In addition, the animals are offered branches on a daily basis. Depending on the method of intake reconstruction (with body weight or body weight$^{0.85}$), this animal (appr. 255 kg) had an estimated daily ration between 11.2 and 9.4 MJ ME, respectively higher than recommendations for a hypothetical 255 kg goat ram (31 MJ ME / day). Also, protein intake was high and trace elements (iron, zinc, copper and selenium) were low compared to goat and sheep requirements. Regarding fibre, the structure of the individual feedstuff seemed too low. Recommendations were made to reduce the energy and highly fermentable carbohydrate content of the daily ration. Also, mineral supplementation was augmented to cover the requirements for goat and sheep. The recommendation for the ram was the following: Grass, hay, lucerne hay, wheat bran, carrots, mineral supplement, selenium supplement and crisp bread for training. Also to offer a lot of branches, like hazel or linden, to provide the takins with enough browse.

KEYWORDS: Takin (*Budorcas taxicolor taxicolor*), claw health, nutrition

Visitors feeding roughage to zoo herbivores

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Actual interaction with animals typically makes a visit to a zoological garden very attractive for visitors. However, visitors may themselves represent a source of distress for the animals on display. Therefore, zoological gardens have to find a compromise between making animals accessible for their visitors, and keeping the animals in protected from the visitors' negative impacts.

A traditional way of facilitating animal-visitor interaction is to allow feeding by the visitors. Such regimes often rely on attractive, highly digestible and hence potentially unhealthy food items, and because of the begging behaviour easily triggered by such regimes, visitor feeding is generally considered an undesired activity unless restricted to high-fibre pellets sold for the use in petting zoos.

The Naturschutz-Tierpark Görlitz initiated a new visitor feeding concept for herbivores such as cattle, sheep, yak, Bactrian camels, pigs and donkeys, where a limited amount of roughage (grass hay or fresh grass) is deposited on the visitor side of an enclosure and visitors can place this in a trough on the enclosure fence. In the case of low visitor numbers, animal keepers ensure that the intended daily amounts are fed. Apart from teaching about the natural diet of the animals, this setup appeared to increase positive associations with visitors on the side of the animals.

In order to investigate the effect of such a feeding regime, we divided enclosure of donkeys and cattle at Görlitz, and of zebus at the Zoological Garden of Halle (where no such feeding regime was in place), into three areas (A: feeding station at the enclosure boundary to visitors; B: other regions of boundary to visitors; C: enclosure parts remote from visitors), and quantified the presence and duration of stay of animals in each region along with the presence and duration of stay of visitors at the enclosure boundary. In the first part of the study during autumn of 2015, the zebus spent more time in region C, and less in regions A and B, than donkeys and cattle. The duration of visitor stay at the enclosure was lower for the zebus than for the other exhibits.

In the second part of the study in 2016, the zebu feeding regime was changed to the visitor roughage feeding setup. Subsequently, in autumn 2016, zebus spent more time in region A, and the duration of visitor stay at the enclosure increased. The body condition of the zebus did not change markedly. Visitor polls suggested a good acceptance of the roughage feeding setup and an increased attractiveness of the exhibit.

In conclusion, facilitating the feeding of (selected) zoo herbivores with roughage by visitors may represent an easy way to increase the attractiveness of enclosures, enhance their pedagogic value, and increase animal comfort by forming positive associations with visitor presence.

KEYWORDS: cattle, donkey, camel, zebu, roughage, visitor interaction

Nutrition of *Dendrohyrax* in Ostrava Zoo

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Ostrava Zoo keeps the only representatives of the genus Dendrohyrax in human care. At the moment, we keep 3,2 of Southern tree hyrax (Dendrohyrax arboreus) partly imported from Tanzania in 2009-2010 and partly born in Ostrava Zoo, and 2,2 western tree hyrax (Dendrohyrax dorsalis) imported from Togo in 2016. These animals are unique both in their anatomy as well as diet. We have founded a Dendrohyrax working group including colleagues from several Czech zoos. The goal of this group is to share our current knowledge about this genus, breed the animals, and create a gene pool of these species in human care. The diet used before consisted mostly of vegetables, fruits and leaves, causing problems of diarrhoea and unformed faeces. The new diet includes leaves as the main part, followed by acacia pellets and a smaller part of green vegetables, carrot and other root vegetables. The present results show substantial improvement in condition of the animals and the occurrence of well-formed faeces.

KEYWORDS: hyrax, browser, leaves, fibre

Teeth and guts: Asian bear nutrition

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As there is a lack of information on the nutrition of wild animals compared to domesticated species, exotic animal nutrient requirements have mostly been derived from domestic animal models. For bears, the closest domestic model is canine or feline. This collaborative study is investigating the appropriateness of these two models for sun bears (*Helarctos malayanus*), sloth bears *(Melursus ursinus)*, Asiatic black bears (*Ursus thibetanus)* and European brown bears (*Ursus arctos arctos)*.

The nutrient requirements for these species have not yet been examined in detail. Dental health issues and pigment deposition in the retina are common occurrences within Southeast Asia. The aim of the study is to compare nutrient and energy intake between species in relation to dental disease by using three validating methods: measuring digesta retention times, faecal scoring, dental health scoring and measurement of oral pH. Data were collected before and after a diet change.

The previous diets of all bears were high in fruits and soluble sugars, and low in fibre, compared to the newer diets which are closer to the nutrient model for canines and more representative of each bear's natural ecology. Digesta retention was observed to be significantly quicker for the sun bears than the other bear species. There was no correlation between oral pH and score of dental disease; however, worse dental scores correlated with older age for all bear species with dental issues beginning as young as four years old.

The different digesta retention of each bear have strong implications for the necessary energy density and food components of their diets. This study could be extended to include other bear species such as the sloth bear to develop better nutrition management methods.

KEYWORDS: sun bear, sloth bear, black bear, browsn bear, faecal score, dental health, oral pH, digesta passage

Nutrition and fertility in pet birds

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During egg production and rearing of nestlings, a lot of health problems (for example disturbances of egg production, egg binding, skeletal disorders in nestlings etc.) occur, which sometimes depend on the nutrition before and within the reproduction period.

A lot of special diets are offered for this time. Moreover, secret formulas circulate amongst breeders to optimize the supply of breeding parents and hatched youngs. But all formulas are based on experience and tradition or are transferred from recommendations for poultry. Investigations in pet birds are rare.

But as known from other species, the fertility in pet birds depends – amongst other factors – also on the nutrition of the male and female birds.

The sperm quality of the cock depends on the zinc, methionine and cysteine level of the diet.

Egg quality is influenced by energy, protein, vitamin E and selenium level as well. Hatchability can be influenced by quality and strength of the egg shell, which depends on calcium and vitamin D supply. The death of the embryo might be caused by several vitamin deficiencies.

Moreover, the body condition score of both males and females play an important role concerning the reproduction rate.

Therefore, aim of the present study was to collect data on laying performance in dependence on different feeding strategies to give guidelines for a successfully reproduction rate.

KEYWORDS: pet birds, fertility, reproduction, egg, sperma

Different nutritional requirements in the family Musophagidae (Turacos)

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The turacos (Family Musophagidae) include 25 species of medium-sized to large arboreal birds with long tail and short rounded wings. All representatives live in sub-Saharan Africa in forests, woodlands or savannas. In term of nutritional requirements, two main groups are recognized, the “banana eaters” *(Tauraco, Musophaga, Gallirex)* and the “leaf eaters” *(Criniferoides, Corythaixoides, Crinifer, Corythaeola)*. The difference between the groups is not only in appearance, but also in nutritional requirements.

The white-bellied go-away bird *(Criniferoides leucogaster)* as a representative of the “leaf eaters” is almost an exclusive herbivore feeding on foliage. Unlike the “banana eaters”, it mostly feeds on the green parts of plants. Unfortunately, also "leaf eaters" are still mostly fed with fruits and pellets for fruit eaters with lack of green food in captivity.

Such a feeding regimes leads to gastroenteritis and kidney disease in many cases, with hypothyreosis, encephalopathy, incomplete muscle formation or degenerative muscle changes, renal tubulonephrosis, energy deficiency, underdevelopment or delayed development of several organs in chicks, and the most important result of all previous listed – immunosuppression. Often a result of suboptimal feeding is also hypovitaminosis E and iodine deficiency.

It can be assumed that the birds drew necessary nutrients supplies from their body reserves when newly imported, especially from the liver. Nutrition in captivity during the first years, even when the birds bred successfully, was not sufficient and correct. Therefore, now is the time to identify the health problems in adults and especially lower viability mortality of chicks in relation to the different nutritional requirements.

KEYWORDS: turaco, herbivore, frugivore, morbidity, mortality

Basic data on nutrition of ostrich, rhea and emu

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The keeping of ostriches (*Struthio camelus*), emus (*Dromaius novaehollandiae*) and rheas (*Rhea americana*) in local zoos as well as in private households repeatedly gave rise to debate in the past. In many cases the question about a nutrition appropriate for species and requirements under local housing and climatic conditions is placed in the center of interest.

Whereas for productive poultry, scientifically sound feeding recommendations have existed for many years, feeding ratites animals occasionally entails difficulties or risks.

Data about energy and nutrient requirements are available. However, this information is still partially incomplete or was generated in the original habitat, so that the question arises to what extend these data hold true under local housing conditions (thermoneutral zone – energy requirement?). Whether on the other hand specifications generated for productive poultry might be transferred to ostriches, emus and rheas has to be questioned due to species-specific needs.

At first, differences result from anatomical conditions. Contrary to the domestic chicken, rheas have clearly pronounced caeca of approximately 30 cm length, which allow a more efficient use of rations high in fibre. Besides these anatomically caused specifications, further attempts should be made to meet the species-specific demands by simulating the natural food spectrum (mainly dry savannah). Whereas commercial poultry is mainly supplied with cereal-rich and, with the exception of ducks and geese, low-fibre compound feed (= concentrate feed), the nutrition of ostriches, emus and rheas is predominantly based on high-fibre and partly highly-lignified grasses. This “forage” is ingested throughout the day in irregular intervals through “grazing”, which should be taken into account when formulating the rations.

The use of compound feed, which was initially formulated for commercial poultry (=reclassification) raises the question to what extend emus, rheas and ostriches tolerate potentially included additives (e.g. coccidiostatics).

In general, the composition of the rations for emus, rheas and ostriches should include to a greater extend feedstuffs that are similar to the natural food spectrum of the original habitat – as far as this is possible (e.g. offer of hay chaff to compensate the natural grazing in the original biotope and hence prevention of possible behavioural problems like e.g. feather pecking).

When drafting scientifically derived nutritional concepts a transfer of data from other species might be inevitable. However, this should be always done with the required diligence and a critical scrutiny to what extend those species are comparable at all with ratites from the nutritional-physiological point of view.

KEYWORDS: ostrich, emu, rhea, nutrition, feed

Birds of prey – nutrition and nutritional disorders

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Birds of prey have been kept in human custody for centuries (hawking/zoos). Moreover, so-called 'hospices' have been established whose purpose is to take temporarily care of injured animals until health is restored and to return them subsequently to their natural habitat. In most cases the birds are usually fed day-old chicks and mice (with supplements). Apart from the hygienic status of these prey items, the chemical composition varies within a wide range.

Aim of this study was to gain qualitative and quantitative ideas on feed consumption, amounts and composition of the usual prey items.

Therefore, several prey items were analysed to get an idea of the energy and nutrient supply. Moreover, health disorders are discussed under a nutritional background.

The typical feed ingestion behaviour of the birds of prey has to be considered (for example: the amount of casts differed markedly between owls or falcons). Higher proportions of ash (indicating mineralized skeleton) were found with higher absolute and relative amounts of cast. The rate of cast production (relative to the ingested feed amount) seems to be a tool to keep the composition of the chyme constant that enters the small intestine (as seen by comparison of really ingested feed, that means feed intake minus cast).

KEYWORDS: birds of prey, prey, nutrition, mice, day old chick

Microbial profiling in faeces of wild vs. captive cheetah fed meat or whole prey

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Mammalian gut microbiota composition may differ according to host phylogeny, gut morphology and dietary habits. One of the strategies to explore the influence of these factors on host-microbe co-evolution and host-level differences is to investigate the natural variation in gut microbial community composition of captive wildlife species and their free-ranging conspecifics. Compared to omnivores and herbivores, the phylogenetic differentiation among microbiomes in carnivores has not been studied in great detail. In this study, we primarily focussed on the faecal microbiota of the largest population ever studied of the captive cheetah (*Acinonyx jubatus*), a strict carnivore with endangered status.
For this purpose, phylogenetic profiling data obtained from 50 cheetahs housed at 13 EAZA-associated zoos were compared to data obtained from a smaller subset of free-ranging Namibian conspecifics. Despite the obvious difference in environmental factors to which the two groups are exposed, community profiling with Illumina MiSeq sequencing, DGGE fingerprinting and quantitative PCR revealed similar microbial species richness and identified faecal core members belonging to *Clostridium* cluster XIVa (8.77-8.97 log10 CFU/g), *Clostridium* cluster I (8.12-8.13 log10 CFU/g) and *Clostridium* cluster XI. However, members of the latter cluster were represented in significantly greater number in captive cheetahs (7.28 log10 CFU/g) compared to free-ranging conspecifics (6.59 log 10 CFU/g). Also, community profiles of captive cheetahs fed only whole chickens did not group with other conspecifics housed in zoos but clustered more closely to profiles of free-ranging cheetahs. This may indicate that changes in substrate availability depending on the supply of different prey components (e.g. viscera and feathers) may drive faecal community differentiation in captivity. Likewise, comparison with faecal samples collected in domestic cats also revealed different microbial structures between cats fed kibble diet and captive cheetahs fed raw meat diets. Remarkably, the faecal microbial composition of one cat feeding on raw meat more closely resembled that of captive cheetahs. These findings support the hypothesis that different dietary habits within members of the *Felidae* may differentiate feline microbiomes to a larger extent than previously thought.

KEYWORDS: Cheetah, captivity, free-ranging, gut microbiota

Survey of feeding practices, body condition and faeces consistency in captive ant-eating mammals in the UK

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A survey was conducted investigating the feeding practices, body condition, and faecal consistency of 26 giant anteaters (*Myrmecophaga tridactyla)*, 13 aardvarks (*Orycteropus afer)*, and 31 armadillos (*Dasypodidae spp)* from 20 zoological collections in the UK. For the latter two, scores for body condition (BCS, from 1 emaciated to 5 grossly obese) and faeces (Faecal Score (FS) from 1 solid to 5 diarrhoea-like) were applied. The majority of the UK collections offered a 'complete' feed for anteaters and aardvarks as opposed to the traditional 'gruel' diet. Armadillos were fed mixed diets of fruits, vegetables, eggs, dog or cat food, and various other items. Grossly obese individuals (BCS >4) were only observed in two armadillo species. The average body mass recorded for giant anteaters was above values reported for wild animals, which was not the case in aardvarks. Anteaters received on average 75% of the amount of dry matter offered to aardvarks, although their basal metabolism is only 60% that of aardvarks; hence, anteaters might have been offered more food than required. The FS for anteaters were higher than for aardvarks or armadillos. Dietary ash, acid detergent fibre and acid insoluble ash (AIA) levels did not correlate with either FS or faecal dry matter (DM). However, there were negative correlations between faecal ash and AIA content with faecal DM and FS, suggesting that measures increasing AIA intake above that achieved by current diets might beneficially influence FS. Only one anteater had a patent parasite infection; this animal had a FS of 5. Results of this survey will encourage careful monitoring of body mass and diet for giant anteaters and armadillo to avoid obesity. Further studies are needed to investigate the impact of higher levels of indigestible material in anteater diets on faecal consistency, growth, and body condition.

KEYWORDS: Giant anteater, aardvark, armadillo, survey study, body condition score, faecal score, diet survey

Asian pangolin nutrition: not what you might expect

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Pangolins are ant specialists that are under intense threat from the illegal wildlife trade. Nutrition has notoriously been their downfall in captivity, and is still an issue in regards to rescue and rehabilitation. We analyzed the nutrient content of diets used by institutions that are successfully keeping Asian pangolins and, to assess the variety of the ingredients and nutrients, compared these with the nutritional requirements of potential nutritional model species. We performed intake studies at five institutions and also had data from three other institutions. We also analyzed 5 different wild food items to use as a proxy of wild diet.

We observed two categories of captive diets: those mostly or completely composed of insects, and those high in commercial feeds or animal meat. Nutrient values were broad and there was no clear rule. The non-protein energy to protein energy ratio of the diets were much higher than the wild food items, more so for those which contained less insects. The average contribution of carbohydrate, fat and protein energy were also further away from the wild samples the less insects the diets contained.

The previously suggested nutritional model for pangolins is the domestic dog, which is supported by our relatively large nutrient ranges of apparently successful diets; however, due to the highly carnivorous nature of pangolins, the upper most nutrient intake data are not consistent with this and favour the feline nutrient recommendations. We are unable to render a conclusion of what model is more appropriate based on our collected data. However, the large range of nutrients is more similar to the canine model.

Pangolins are not as nutritionally sensitive as once thought. The true challenge lies in palatability.

KEYWORDS: pangolin, palatability, insectivor, protein

Does chitin create a bias in crude protein analysis?

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The crude protein content in feed and food is one of the major determinants of its nutritional value. The standard - Kjeldahl analysis - assumes all nitrogen to originate from protein, resulting in a loss of accuracy when non-protein nitrogen is present. When determining the crude protein content of insect containing diets, the nitrogenous non-protein compound chitin is introduced. The aim of the present study was to analyze the impact of chitin presence on crude protein content and to develop a method to correct for this overestimation. The nitrogen content of several substrates was determined using conventional Kjeldahl analyses and calculated based on amino acid analyses. Additionally, Kjeldahl analyses were done on the chitin extract of each substrate. For pure chitin, the conventional Kjeldahl method resulted in a total of 61.6 g N/kg, which equals 385 g crude protein/kg, whereas calculations based on amino acid analyses only resulted in 0.5 g N/kg. These findings indicate the importance of correcting crude protein analyses of chitin containing diets for the presence of chitin-nitrogen to prevent overestimation of true protein content. Especially for growing or lactating animals where more attention is needed to cover protein demands, the crude protein content may not be sufficient in case of chitin-rich items such as insects, crustaceans and mushrooms, to evaluate adequate protein supply. Also when analysing natural diets of insect eating animals, it has to be taken into account that not all Kjeldahl nitrogen is protein, in order to prevent overestimation of the protein requirement of insectivores and other insect eating animals.

KEYWORDS: chitin, insects, Kjeldahl, nitrogen, crude protein

Insects as feed for zoo animals

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Insects are the largest animal class. Several dozen insect species are used as a source of feed for amphibians, reptiles, birds and mammals. The nutrient composition differs between species, but also between developmental stages within a species. Furthermore, the diet provided to these insects, but also abiotic factors during rearing, have an effect on their composition.
Whereas for certain zoo animals insects are primarily a form of enrichment, for others their complete diet may consist of insects. Especially in the latter situation, insect composition is vital for the health and wellbeing of the consuming animal.
Commercially available insects are a good source of most nutrients for captive insectivores. However, certain nutrients are present at low concentrations, and could lead to deficiencies. This in turn can affect the health, wellbeing and productivity of the consuming animal. Some examples of these potentially limiting nutrients are calcium, vitamin A and carotenoids, vitamin D and E, and omega 3 fatty acids.
The focus of this talk is to provide an overview of available feeder species, their nutrient composition, and how this composition can be altered to better suit specific nutrient requirements. Lastly, some information on the basics of insect rearing is provided.

KEYWORDS: insects, feed, composition, dietary adaptation, nutrition

Whole fish feeding in zoos - Nutrient analyses and losses during six month of storage

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Whole fish is an important feedstuff in zoo animal nutrition. The knowledge on its nutritional composition is limited in Europe. Most published European data are based on fish muscle meat, which does not reflect the composition of whole fish. It is said that storing has a negative effect on the nutrient composition of whole fish. However, the exact degree of vitamin and trace element losses during storage in whole fish is relatively unknown. The aim of this study is to conduct nutritional analysis of whole fish (originating from the same catch) and to quantify nutrient losses during a storage period of 6 months. Two fish species, herring (He) and capelin (Ca) were analysed from this ongoing study. To this date, the results of three different zoos are present (Z1, Z2, Z3). Each species was tested at 4 time points, at delivery to the zoo and subsequently every 60 days (time points 0d, 60d, 120d, 180d). During these six months, the fish were stored in the zoo as they normally would before feeding. A homogenized sample of thawed whole fish was analysed at each time point for the following nutritional components: Water, vitamin A, vitamin B1, vitamin D3 and vitamin E as well as the trace elements Cu, Fe, Se and Zn. At 0d and 180d, a proximate analysis (crude protein CP, crude fat EE, crude ash CA) and bomb calorimetry (gross energy GE) were performed. If a nutrient could not be detected in the analysis, it was not measured in subsequent samples.

Nutrient composition of herring (He) and capelin (Ca) from three zoos (Z1, Z2, Z3) on dry matter basis at delivery and 6 months, ↓ indicating a reduction and ↑ indicating an increase

Fish		Time	CP %	EE %	CA %	GE kJ	Fe mg/kg	Zn mg/kg	Se mg/kg	Vit D3 IU/kg	Vit E mg/kg	Vit A IU/kg
Z1	He	0d	43.4	38.8	7.1	26.5	29.7	33.6	1.1	15905	7.8	14672
		180d	↓40.1	↓37.5	↓4.8	↓24.5	↑42.9	↑42.2	1.1	↓13661	↑9.8	↑19994
Z2	He	0d	52.2	27.9	6.8	24.8	55.4	40.1	0.7	13464	11.6	13318
		180d	↓43.6	↓24.1	↓5.8	↓19.1	↓51.4	↓36.3	↑1.2	↓6955	↑11.8	↓10952
Z3	He	0d	34.0	36.7	5.3	23.1	35.3	29.5	0.9	16009	9.6	12667
		180d	↑50.1	↓31.9	↑8.1	↑24.2	↑48.8	↑44.3	↑1.4	↑20058	↓8.3	↑16470
Z1	Ca	0d	62.4	19.2	11.2	20.4	47.9	67.7	1.1		60.7	19589
		180d	↓43.9	↑32.5	↓7.0	↑23.9	↓11.4	↓13.6	↓0.2		↓7.0	↓5790
Z2	Ca	0d	50.8	34.1	7.1	26.0	36.6	49.9	0.6		44.6	18463
		180d	↑51.2	↓22.4	↑8.8	↓22.4	↑40.1	↑52.6	↑0.9		↓21.6	↓13768
Z3	Ca	0d	54.6	27.8	9.6	21.5	41.2	58.7	1.1		48.0	20980
		180d	↓41.5	↓22.2	↓6.4	↓19.3	↑43.5	↑59.2	↓1.0		↓24.4	↑21204

Cu was below the detection limit of 0.1 mg/kg original matter (OM) and vitamin B1 below the detection limit of 0.2 mg/kg OM. In capelin, vitamin D3 was undetectable (lower than 1000 IU/kg OM). Zinc and vitamin E concentrations were higher in capelin, which is commonly considered to be low in fat. However, calculated on dry matter basis, it was not generally the case (19.2 - 34.1% DMB). Vitamin E (antioxidant for free fatty radicals) in capelin are almost halved during a storage time of six months. Regarding proximate analysis, fat and protein content of whole fish was generally reduced during storage, simultaneously reducing the fishes' gross energy content. This could be due to fat oxidation during storage. Storage has a high impact on whole fish nutrient content and should be reduced to under six months to avoid fat, gross energy and vitamin E losses.

KEYWORDS: whole fish composition, nutrient losses over storage time

Habitat selection, temperature ranges and implications for nutrition and body condition in a high Andean amphibian, the Titicaca water frog (*Telmatobius culeus*)

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Temperature has a profound effect on biological processes influencing the fitness of ectotherms such as metabolic rate, feeding, digestion, and by extension their immunity, growth and reproduction. In aquatic organisms, the availability of food resources is also related to temperature zones. Food restriction, or a low quality food, can have an impact on the immune system of an amphibian and should be considered in amphibian husbandry. Here we present a study case about feeding strategies and thermal challenges of a high-altitude, fully aquatic amphibian of the Bolivian Andes, the Titicaca water frog (*Telmatobius culeus*), endemic to Titicaca Lake, which in the last years has been facing abrupt declines. Lately, captive breeding programs have been started with this species. We present information about temperature ranges at different depths of the lake and preferred temperatures of the species, which we compare with the prey availability and its impact on nutrient intake in two age stages (juveniles and adults associated with depth). We also present information on the feeding ecology and trophic level of this species at different depths in two age stages, using ^{13}C and ^{15}N stable isotope composition of frog tissues and potential preys.

T. culeus is annualy exposed to temperatures fluctuating between 11.5°C and 17.6 °C and it seems that the species prefers depths with a more stable temperature around 15°C. In early stages of life, the animals are not only under a greater temperature stress with higher fluctuations of 3.56°C compared with 1.48°C in deeper areas, but they also have access to only a portion of the food resources available in the lake compared with older stages at other depths were frogs have access to wider resources spectra. These patterns also show a nutrient restriction such as access to protein and fat levels that are lower (37.4% to 45% of CP and 1.05% to 5% fat) in prey items at low depths compared with higher values in the items available in deeper regions (53% to 75.4% of CP and 7.7% to 13.7% fat). This is also reflected in the stable isotopic analysis: early stages are occupying lower trophic levels in the $\delta^{15}N$ than larger frogs. These observations also correlate with the body conditions of this two age groups where juveniles and subadults in shallower waters have a lower body condition than subadults and adults living in deeper areas. These temperature fluctuations have been shown to affect metabolic rate and energy intake, hence nutrient requirements, especially in the case of juveniles due to their higher requirements. This natural thermoregulatory behaviour should be taken in account in captive breeding programs: in most cases animals are fed almost at libitum and at constant temperatures, with the risk of nutritional disorders such as obesity, hypervitaminosis and overload. With wrong constant temperatures, an amphibian cannot maintain its body temperature appropriately and it will fail to thrive in captivity, including effects of suboptimal temperature on the immune system.

KEYWORDS: amphibian, nutrition, temperature

Bone densities in three different populations of Common Spadefoots (*Pelobates fuscus*) by using computed tomography

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Captive rearing programs have been initiated to save the common spadefoot toad (*Pelobates fuscus*) from extinction in the Netherlands. Evaluating whether this species needs UVB-radiation and/or dietary supplementation for healthy bone development is a crucial part of these conservation efforts. The bone densities in femurs and skulls of common spadefoot (n = 51) were measured in Hounsfield units (HU) by computed tomography. One group (n = 21) was reared without any exposure to UVB radiation. The adults were fed worms (Lumbricidae) and crickets (Gryllidae), dusted with Gistocal® (Beaphar, Hedel, The Netherlands). The juveniles were fed blanched *Cichorium endiva* and 3-Colour Sticks Premium Fish Feed® (Velda, Enschede, The Netherlands), Spirulina Flakes® (Ocean Star International, Snowville, USA) and TetraMin XL Flakes® (Tetra, Melle, Germany). Another group (n = 18) was reared and kept in an outdoor breeding facility with availability to direct sunlight. The diet of the adults consisted woodlice (Oniscidea), crickets (Gryllidae), earthworms (Lumbricidae) and mealworms (*Tenebrio molitor*), without any further dietary supplementation. The juveniles were fed TetraMin® (Tetra, Melle, Germany) and JBL Spirulina® (JBL, Enschede, The Netherlands). The third group were wild specimens (n = 12). No significant difference was found between the HU units in the femurs of both captive adult groups and wild adults. Considering the bone density observed in wild specimens, the findings suggest that this species was not sensitive to develop metabolic bone disease in either captive setting. But dietary supplements did seem to have a positive effect on the bone development in this species.

KEYWORDS: Common Spadefoot, bone density, computed tomography, dietary supplements, UVB radiation

Large-scale production of nutritious rotifers to enhance the reproductive capacities of ornamental fish

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The aquarium industry has continuously grown for more than three decades, thanks in large part to the availability of manufactured feeds. These were first developed some 60 years ago based on extrapolation of results derived from work with food fish under intensive farming conditions. However, such extrapolations should be made with caution when applied to ornamental fish species. Most farming diets are formulated to (1) produce a fish that grows rapidly, often using metrics related to meat production and not necessarily long-term health, and (2) use of least-cost formulations. These parameters are not necessarily associated with reproductive capacities, because commercially produced species are not reared to reproductive maturity.
The situation is different in the aquarium trade, especially public aquariums that are involved more and more in reproductive programmes covering an increasing number of species ranging from freshwater and marine fish to invertebrates such as corals. Live feeds are an essential component in the diet of many reared fish species, especially during the first feeding stages of development. In this respect, ornamental fishes are similar, in particular coral reef fish. Because larval fish are well-adapted to feed on small zooplankton in the water column, live prey items such as *Brachionus* rotifers, *Artemia*, and the cilicate *Paramecium* are widely recognized as the feeds of choice, at least until the fish reach the juvenile stage and are able to efficiently feed on processed diets.
Saltwater rotifers (*Brachionus* spp.) have proven to be the most effective first feed for larval zebrafish. Larvae that feed on nutritionally optimized rotifers for at least the first few days show very high survival and develop rapidly. The use of rotifers with larvae in “polyculture” (larvae, rotifers, and rotifer feed) requires minimal labor and makes it possible to eliminate any use of Artemia, saving considerable expense and labor. Some zebrafish facilities find it beneficial to continue to feed rotifers to their fish for as long as 60 days after beginning to feed dry feeds.
However, producing enough rotifers to meet the nutritional requirements for larval feeding can be challenging. This protocol describes a method whereby millions of rotifers can be produced each day for a minimal cost. A 20 liter bucket is a typical setup for a small system, which is easy to move around and easy to clean. Such a bucket containing ~15 L of water at 500 rotifers/mL (low density) will hold roughly 7.5 million rotifers and yield 2.5 million rotifers per day at 33% daily harvest. Importantly, the system harnesses both the natural high productivity of the rotifers and the behavioral preferences of the fish, and the labor involved with maintenance is low. This protocol presents an updated, step-by-step procedure that incorporates rotifer production (scalable to any desired level) for use in a polyculture of zebrafish larvae and rotifers, to promote maximal performance during the first 5 days of exogenous feeding and beyond.

KEYWORDS: aquarium, fish reproduction, rotifers, zooplankton, live feed

Revising the diet of sea dragons (*Phycodurus eques*) to reduce mortality during relocation

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Den Blå Planet, a large Aquarium in Denmark, had experienced a high morbidity and mortality in their newly acquired group of sea dragons. 16 out of 20 sea dragons died within a short period after arriving at the Aquarium. The autopsies revealed infestation with opportunistic parasites. The fact that these parasites caused such widespread disease and death in the group might have been indicative of stress and a compromised immune status. The stress was likely connected with the transport and the change in environment for the newly introduced animals. In aquaculture, the physiological condition of the animal is thought to determine its chances for survival under stressful circumstances. To increase the chances of survival for a new group of sea dragons that was planned to arrive at the zoo, we decided to optimise the diet with focus on supporting feed intake and preventing energy depletion; supporting the immune system; supporting the gut - a healthy gut helps maintain a healthy immune system; optimising fatty acid intake and ratio; increasing level of antioxidants to counter the formation of free radicals; streamlining nutrient supply; increasing available high quality protein; balancing vitamin and minerals in the diet.
Information on the optimal nutrition of sea dragons is scarce. A comparative approach was adapted, using sea horses and other aquatic species as a model. These particular sea dragons were only used to eating live prey and were reluctant to take any manipulated prey such as frozen *mysis*. The previous group had been fed live *mysis*. The new strategy was to gutload the *mysis* prior to feeding them to the sea dragons, as it seemed the only feasible way of changing the diet. The diet fed to the *mysis* could be tailored to increase their nutritional value for the sea dragons.
The new diet was developed as a joint effort between nutritionists, feed producers, veterinarians and the sea dragon keepers. A gel was decided upon as the best vehicle for the diet, to accommodate the eating habits of the *mysis*. The gel was formulated to include fish meal, salmon oil and spirulina to achieve high quality proteins, as well as omega 3 fatty acids such as DHA and EPA. Mannan oligosaccharides (MOS) was included, as studies show a beneficial effect on gut flora and villi growth in other aquatic species. Selenium levels and vitamin E levels were adjusted for antioxidant properties. Micronutrients were balanced according to the recommended amounts for model species such as sea horses and other aquatic species where information was available.
The gel was fed to the *mysis* in their holding tank, for gutloading purposes, and the *mysis* were fed to the sea dragons as the staple diet. The morbidity and mortality was considerably lower after implementing the new feeding regime. The aquarium only lost 4 sea dragons out of 20, and the overall health of the sea dragons improved. The results might be relevant for other aquatic species, as changes in environment greatly affect most animals living an aquatic life.

KEYWORDS: Sea dragons, mortality, diet changes, immunonutrition, aquatic species

Micromineral tissue distributions across ornamental fish species

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Keeping ornamental fish in mixed exhibits comprises the challenge of providing the wide variety of species with adequate amounts and proportions of nutrients. Studies identifying requirements in such a setting are facing methodological difficulties, and are therefore scarce. Because of the concerns of both micromineral deficiency and toxicity in ornamental fish, information is needed on the strategies across ornamental fish species to deal with microminerals. We involved three adult non-reproductive fish of each of 10 ornamental fish species kept under the same water and dietary conditions: albino grass carp (*Ctenopharygodon idella*), golden orfe (*Leuciscus idus*), golden tench (*Tinca tinca*), goby (*Gobio gobio*), comet tail (*Carassius auratus*), rudd (*Scardinius erythrophthalmus*), sarasa comet (*Carassius auratus*), golden shubunkin (*Carassius auratus*), sturgeon (*Acipenser sturio*), blue gill sunfish (*Lepomis macrochirus*).
After euthanasia, their liver, heart, long muscle and tailfin were dissected, and stored at -20°C until analysis. Samples were homogenised, and subject to analysis of Fe, Cu and Zn through ICP-MS. Means of log-transformed data were compared with repeated measures anova with species as between-subject factor and tissue as within-subject factor. Pearson correlations were calculated per mineral between organs across species.
A remarkably wide range in mineral concentrations were found across the species. Despite interindividual differences, many interspecies differences were significant (P<0.05). In liver for instance, over 100-fold differences were measured, sometimes exceeding concentrations considered toxic in other species. Similar to other animals, the concentrations were typically highest for Fe, followed by Zn and then Cu. For all three studied microminerals, positive correlations existed between hepatic and cardiac concentrations, and between muscular and tail concentrations, with no correlations between for instance liver and muscle concentrations. Some species contained high levels of microminerals in their body muscle and tailfin. Others had high mineral levels in their liver. In agreement with other species, especially Zn was considerably stored in tailfin (median 88 mg/kg; range 48-223 mg/kg), even in significantly higher concentrations than in liver (median 51 mg/kg; range 4-1118 mg/kg). The findings also indicate that the non-lethal sampling for mineral status through clipping a piece of (tail)fin, might give a reflection of muscular concentrations, but not a suitable technique to estimate the animal's overall mineral status. The particular finding of high mineral concentrations in heart in comparison with other animals is still a matter of further study.
In conclusion, the micromineral distribution throughout the body differs substantially between ornamental fish species, with different strategies for storage of excess microminerals. Although requirements cannot be derived from these data, they suggest different micromineral requirements among ornamental fish species, that might need to be considered in the feeding of mixed aquaria. These data urge for further study on potential under- of overfeeding of minerals to ornamental fish and its implications on reproduction and longevity.

KEYWORDS: zinc, copper, iron, tissues, fish

POSTERS

Molybdenum status in ruminants

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The natural Mo content of food meets the Mo requirement of ruminants of less than 100 mcg / kg food dry matter (fdm). Mo deficiency symptoms were only detected when ruminants received a semisynthetic diet. However, the biological importance of Mo for ruminants is in the toxicological range. The effect of high Mo amounts on ruminants is species-specific. Whereas cows respond on 1-2 mg Mo/kg fdm with diarrhoea and 300 mg Mo/kg fdm caused diarrhoea in domestic sheep, domestic goats tolerated 1000 mg Mo/kg fdm without diarrhoea. Its interaction with Cu and S reduces the bioavailability of Cu in ruminants and produces secondary Cu deficiency symptoms. The Mo concentrations of liver and kidney are good indicators for the Mo status in ruminants. Furthermore, the Mo concentrations in hair, milk and bones respond on a different level to high Mo content in the diet.
Due to the species specifity of the Mo status, organ tissues of different wild ruminant species were analysed and compared.
The investigated wild ruminants, which were kept in captivity, 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. For the presentation of the results, the various species of ruminants were classified as the ruminant feeding types browsers, intermediate mixed feeders, and grass and roughage eaters.
After dry ashing of samples the Mo concentration was analyzed by optical emission spectroscopy with inductively coupled plasma.
The Mo concentration of liver, kidney and spleen contained the highest Mo concentrations. This is in accordance with results obtained in domestic ruminants. Among ruminant species it seems that gazelles accumulated the highest mean Mo concentrations in the liver (3.0-5.1 mg/kg dry matter) followed by ibex and sheep.
Adult ruminants accumulated higher Mo concentration in liver, kidney and lung than in neonates; cerebrum, skeletal muscle, heart, aorta, pancreas and hair of the adult ruminant species contained less Mo than in neonates.
Furthermore, feeding types had an effect on the Mo content of organ tissues, but to a lesser extent than Cu and Ti. Adult browsers and intermediate feeders with tendency to browsing stored more Mo in cerebrum, aorta and spleen than the other feeding types. In the liver of intermediate feeders, higher Mo concentrations were found than in the liver of browsers and grass and roughage eaters.
When the Mo concentration in organ tissues was relative low, like in cerebrum, rib and aorta, adult female ruminants significantly accumulated more Mo than males. No differences between male and females ruminants were detected in organ tissues with high Mo concentration like liver and kidney.
The habitat seems to have effect on the Mo status. Adult browsers of Southern California accumulated 3 times more Mo in the liver than in Central Europe, whereas the livers of intermediate feeders with tendency to grass and roughage eaters and sheep contained 2 times of Mo of the livers found in the corresponding animal species in Central Europe.

KEYWORDS: Molybdenum, ruminants

From man to cheetah: adapting the *in vitro* simulator of the human microbial ecosystem to a dynamic feline gut simulation model for the mechanistic study of dietary interventions

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Providing a nutritionally complete and balanced diet to zoo animals is considered one of the key elements for their health and welfare in captivity. Moreover, diet is also a strong mediator of host-gut microbial symbiosis, thereby influencing microbial community and functions, host metabolism and disease risk or development. In human microbiome research, dynamic *in vitro* gastrointestinal simulation models have been proven a useful platform to study mechanistic effects of dietary or therapeutic interventions on microbial metabolism and intestinal homeostasis. For animals with vulnerable status and/or limited sampling access, such models could offer a tool for reproducible and non-invasive analyses and monitoring of intestinal processes in response to dietary components.
This study sets the stage for the adaptation of the well-validated Simulator of the Human Microbial Ecosystem (SHIME) to a dynamic feline gut model mimicking the gastrointestinal tract (GIT) of the strictly carnivorous cheetah (*Acinonyx jubatus*) under carbohydrate-depleted, protein-rich conditions. Essentially, the model consists of a three-stage sequential reactor system inoculated with fresh cheetah faeces from which effluents were subjected to SCFA and ammonium analyses, microbial community fingerprinting and untargeted metabolic fingerprinting. Under adapted nutritional and physiological conditions that approached those of the cheetah gut, microbial communities reached compositional and functional stability after two weeks and this steady-state was reproducible between parallel reactors. Upon stabilization, we monitored the fermentation potency in the simulated cheetah gut by challenging it for a 10-day period with hydrolyzed and non-hydrolyzed forms of collagen, a typical constituent of the strict carnivore's diet. Fermentation of hydrolyzed collagen resulted in an increase of acetate and total SCFA production and a significant increase of proprionate production compared to non-hydrolyzed collagen. Taking into account control vessels without supplementation, non-hydrolyzed insoluble collagen fibrils appeared to be inert, and their presence in fermentation fluid resulted in an overall decreased SCFA production. Although corresponding microbial changes were not significantly different, preliminary short-term batch fermentations (24h) with the same components already revealed an increase of *Clostridium* cluster XI and *Lactobacillaceae*, two core members of faecal microbial community in captive cheetahs.
Although additional fine-tuning is required for specific host species, the dynamic feline gut model mimicking the GIT of the cheetah offers a powerful tool for the analytical assessment of compositional and functional consequences of different dietary nutrients on microbial dynamics and metabolic homeostasis in a strict carnivore.

KEYWORDS: cheetah, in vitro gastrointestinal simulation, gut microbiota, metabolomics

Nutrient composition of whole African clawed frogs (*Xenopus laevis*)

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Many predators include whole frogs in their diets. In captivity, these prey species often are replaced by other whole vertebrates, but there are some species that do not accept substitute items in their diet. Likewise, frog meal has been tested as an ingredient in commercial diets for poultry as well as fish. The African clawed frog (*Xenopus laevis)* is widely utilized in experimental studies, but there is a lack of information regarding its nutrient composition and therefore its suitability as an ingredient in diets. The aim of the study was to determine the chemical composition of this common laboratory frog, and compare its nutritional potential to other frog species as well as whole prey used in zoos.
Adult frogs of both sexes (n=8 females, n=13 males) were analyzed for proximate composition (dry matter, crude protein, fat, ash), aminoacids and selected minerals. Animals were fed pellets made in our facilities, containing on average 91.8% dry matter (DM), 38.6% crude protein, 11.4% fat and 18.8% ash (DM basis), three times per week. Crude protein and fat concentrations of frogs were 53.2±2.9% and 18.4±4.2% respectively. Significant differences among sexes were found in ash (12.5±2.2 vs 15.6±2.4%, p=0.007), calcium (46.1±9.8 vs 59.7±10.6 g/kg, p=0.008), iron (166±44 vs 280±58 mg/kg, p<0.0001) and selenium (1.2±0.2vs0.9±0.1mg/kg, p<0.0001), between females and males respectively. Protein and fat values varied in comparison to other species of frogs and toads that have been reported, and, in general, fat content could be considered lower, and ash content higher in frogs compared to adult laboratory-reared rodents and/or poultry species fed as whole prey. No gender differences were found in amino acid content (on DM), although males showed slightly higher values in the total concentration (g/kg DM). Amino acid values were higher compared to *Rana ridibunda*; in comparison to other species, the contribution of histidine, serine, cysteine and methionine to total protein content were similar to those found in beef, lamb, chicken, turtle, fish and shrimp muscle as well as several organs (beef kidney, heart, liver and lungs), but others differed. Regarding minerals, calcium and phosphorus were similar to other frog species, and are within ranges seen for several whole prey species. However, differences found between sexes should be further evaluated in terms of the effect(s) on immune response and protein structures as well as oxygenation status of the frogs. The chemical composition of *X. laevis* might provide important correlations with nutrient requirements of frogs in captivity. Likewise, these nutrient data can be applied as another whole prey alternative in captive feeding programs; amino acid and mineral details in particular are useful for diet assessment in animals specialising in frog consumption, either regularly or seasonally.

KEYWORDS: Whole frog, nutrient, amino acid, minerals

Estimating food intake in group-fed animals of heterogeneous body size

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Although values of food intake are often expressed as if they represent a linear function of body mass (BM) - for example, as % of BM (i.e., assuming intake ~ $BM^{1.0}$) - a large number of inter- and intra-specific studies have shown that this is not correct. Rather, food intake scales similar to energy requirements (i.e., assuming metabolism ~ $BM^{0.75}$) in an allometric fashion, with suggested scaling exponents ranging between $BM^{0.67}$ to $BM^{0.90}$. In theory, therefore, intake (or amounts to be fed) should be expressed not 'per kg BM' or in '%BM', but as 'g per $kg^{0.75}$'.
Nevertheless, when using data for a certain species, this is usually not problematic, as within most species, the body mass range is narrow, so if a value in %BM is correct for the species, using it as a rough guideline will not produce a relevant error. The important thing is to remember not to transfer such data to other species of different body size. Because of the allometric scaling, food intake in %BM is higher in smaller species, and lower in larger species, when using the same kind of diet.
However, the scaling might become relevant if the food intake of a group of animals with heterogeneous body mass distribution must be estimated - for example in a situation where the total amount of hay fed to a group of giraffes (consisting of adults, subadults and juveniles) is known, but the intake of a specific animal should be estimated. Due to the allometric scaling of food intake, using %BM in this situation is likely to overestimate the intake of the larger, and underestimate the intake of the smaller indivduals of the group.
In such a situation, the best approach is to first estimate the individual BM of all animals, then calculate the metabolic body weight (MBW, $kg^{0.75}$, or using another exponent if adequate) of each individual animal, and then summing up these individual values, divide the total amount of hay by the sum of MBW, and multiply by the MBW of the individual animal in question.

KEYWORDS: food intake estimation, allometric scaling

Digestive separation mechanisms in two carnivorous species: the cheetah (*Acinonyx jubatus*) and the domesticated dog (*Canis familiaris*)

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Separation mechanisms in the digestive tract that selectively retain either fluids or particles have been described in many herbivore species. There is reason to believe that separation mechanisms are present in carnivores fed a texture-rich diet (i.e. high in animal fibre) as well. Wolves seem to show differences in faecal consistency when fed whole prey (texture-rich). In the literature, two types of faeces are described based on their structure, namely firm faeces and dark, watery, loose faeces. In dogs it is known that the water content of faeces is higher in the afternoon than in the morning in morning-fed dogs fed certain diets. It is possible that digestive separation mechanisms underlay these observations in carnivores.
During two studies at the Laboratory of Animal Nutrition on digesta retention in dogs and cheetahs, similarly, two types of faeces were observed. The dog study consisted of six dogs fed two diets, i.e. chunked day-old chicks differing in particle size (7 mm vs 13 mm) in a cross over design. The study objective was to compare digesta passage between the two diets. Interestingly, dogs from both dietary groups defecated firm, dry faeces in the morning and loose watery faeces in the afternoon (AM= 24:00h - 11:59h; PM: 12:00h - 23:59h). The faecal consistency was scored for every sample using the Waltham faeces scoring system based on visual appearance (from 1 = 'hard, dry and crumbly faeces' to 5 = 'watery diarrhea'). Half-scores were used, giving a total of 9 possible categories. Since faecal scoring is subjective, faecal dry matter was taken as an objective measure to evaluate the time difference in faecal consistency. In general, a score of 2-2.5 was typically observed in the morning whereas a score of 4-4.5 was mostly observed in the afternoon. Faecal dry matter content and faecal score correlated well in (R^2= -0.722, $P<0.001$). Faecal dry matter was affected by time of day ($P=0.017$) but no interaction was found between diet type and time of day.
A study on digesta passage in cheetahs (Leemans et al., 2014) showed similar faecal separations. Five adult female cheetahs were fed donkey carcass parts with additional organ supplementation. Some cheetahs defecated once per 24 hours, others defecated twice a day (morning and afternoon). Faeces produced in the morning tended to have a higher dry matter content, although the difference was not significant ($P>0.05$). Faecal scoring was not carried out in this study.
Further analysis on these faecal samples such as animal fibre content (Depauw et al., 2011) and digestibility for firm faeces and liquid faeces respectively could be interesting to unravel the possible separation mechanisms in carnivore digesta, the behaviour of animal fibre (texture) in the carnivore gastrointestinal tract and the impact of incomplete sampling on the interpretation of studies.

KEYWORDS: *Carnivore, faecal separation mechanism, animal fibre*

The effects of dietary nutrient density on growth and nutrient metabolism in macaw chicks (*Ara* spp.)

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For management of captive parrot populations and conservation programs it is important to optimize hand-rearing diets used in breeding facilities. Information on feeding ecology of wild parrots and digestive physiology is required to formulate appropriate diets. Fat contents of hand-rearing diets for macaws typically range from 5 - 21%, which is lower than published crop contents of wild Scarlet macaws (*Ara macao*) (28.6%). This study aimed to evaluate the impact of increasing dietary nutrient density on growth and nutrient metabolism in macaw chicks.

Two hand-rearing diets were formulated, one had a normal density (ND) of nutrients, whereas the other had a high density (HD) with less starch (33 vs 17%) and higher fat levels (15 vs 25% fat). Nutrient levels were adjusted to reach similar nutrient levels on ME basis. Thirty-five macaw chicks of four species (*Ara glaucogularis*, *A. chloroptera*, *A. rubrogenys*, *A. macao*) were housed at the breeding facilities of Loro Parque Fundación in Puerto de La Cruz, Tenerife. After hatching, chicks were blocked per species and, if applicable, also per clutch and within block randomly assigned to a dietary treatment. After hatching, chicks were fed the ND diet and after ~13 d half of the chicks switched to the HD diet. Diets were mixed with water of 39°C in 28:72 ratio. Chicks were fed between 6:00 and 23:00 h. Feeding level of each feeding was ~10% of the chick's body weight (BW) and according the zoo's standard procedures and adjusted by the experienced caretakers. Number of feeding times depended on the chick's age. BW and feed intake were recorded daily, crop emptying rate after the first meal and pH of fresh excreta weekly. Plasma amino acids and acylcarnitines were determined at 40 d of age. Prior to blood collection (0.3 ml), chicks were fed 15% of their normal feeding. Growth rate was calculated from a logistic model fitted to BW data. Data were analysed using ANOVA by PROC GLM and MIXED in SAS.

The amount of feed delivered was similar for both diets (ND 6716 and HD 6571 g DM, P=0.822) but HD-fed chicks showed higher growth rates compared to the ND-fed ones (0.145 vs. 0.134 g/d, P=0.009). Maximum BW tended to be higher for macaws fed the HD diet (935 vs. 896 g, P=0.092) and feed conversion efficiency was similar between treatments (ND 0.109 and HD 0.120, P=0.380). Differences in growth performances relate to a higher amount of protein and energy per g diet for the macaws fed the HD diet (cumulative energy and protein intakes for 74.9 MJ and 1193 g vs. 94.6 MJ and 1507 g for HD diet). It seems that macaw chicks processed the HD diet more efficient. Crop emptying rate was similar between groups (ND 19.4 and HD 19.8 %/h, P=0.718), which may be related to the relatively empty distal parts of the intestinal tract and the similar physical structure of the diets. Increased blood C5 and C5:1 concentrations (P=0.043 and P=0.042, respectively) suggest elevated branched-chain amino acid catabolism that may relate to the higher protein intake. This was, however, not reflected in the excreta pH, which was similar between groups (ND 6.12 and HD 6.03, P=0.655). The increased amino acid catabolism may also indicate that amino acids are used for oxaloacetate (instead of carbohydrates), which is required for fat derived acetyl-CoA utilisation in the Krebs cycle. This was associated with a higher 3OHC4:C2 ratio for the HD group (1.61 vs. 2.18, P=0.027), which implicates a less efficient fatty acid oxidation and energy utilization.

In conclusion, growth of macaw chicks was increased by feeding the high nutrient density diet at the standard feeding level, which was associated with an altered nutrient metabolism. The impact on digestive functioning and on chick's health later in life requires further study.

KEYWORDS: Ara spp., hand-rearing feed, energy density

Milk composition of Indian rhinoceros (*Rhinoceros unicornis*) and its changes over a lactation period

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The objective of this study was to determine the major nutrient composition of Indian rhinoceros' milk (*Rhinoceros unicornis*) over the course of a year to add more information to the pre-existing database of animal milk composition and to compare the results to those of previous studies as well as other hindgut fermenters, elephant and horse. Milk samples were collected from two Indian rhinoceros cows from Zoo Basel. From the first, Quetta, three milk samples were collected and analyzed (colostrum, milk one week and two weeks post-partum). From the second, Ellora, samples were collected regularly over the course of a year and fifteen were chosen for the analyses (from colostrum to 13 months post-partum). The following parameters were measured in milk samples: Dry matter (DM), crude ash (CA), crude protein (CP), ether extract (EE), lactose, calcium (Ca), phosphorus (P), magnesium (Mg), fatty acids (FA) and gross energy (GE). DM, CA, CP and CFa were determined with proximate analysis and nitrogen-free extract (NfE) was subsequently calculated. Lactose was analyzed with infrared spectroscopy and an enzymatic method, Ca, P and Mg with an autoanalyzer, FA with gas chromatography and GE with bomb calorimetry. The composition of Elloras' colostrum was: 13.8% DM (on whole-milk basis), 4.8% CA, 61.8% CP, 0.7% EE, 32.6% NfE, 26.7% lactose, 0.59% Ca, 0.13% P, 0.2% Mg (on DM basis (DMB)), 20.3 MJ/kg GE DMB. Elloras' sample collected 13 months post-partum averaged 8.0% DM (on whole-milk basis), 3.6% CA, 16.3% CP, 1.8% EE, 78.3% NfE, 84.7% lactose, 0.54% Ca, 0.14% P, 0.09% Mg (DMB), 17.43 MJ/kg GE DMB. The main FA in Ellora's and Quetta's samples were capric acid (C10:0), lauric acid (C12:0), palmitic acid (C16:0), oleic acid (C18:1n9c) and linoleic acid (C18:2n6c). Regarding the fatty acid profile, the milk of the Indian rhinoceros is similar to that of the African elephant. Crude analysis showed that the milk of the Indian rhinoceros contains low EE and CP concentrations but high lactose concentrations, which is comparable to the milk composition of other rhinoceros species and horses, however not to elephants. Nevertheless, with higher EE levels, slightly lower lactose and Mg values and a different FA profile, horse's milk is not an optimal substitute for the rhinoceros' calves, unless it is substituted with a fat source that has a similar FA profile to rhinoceros milk and additional lactose.

KEYWORDS: Indian rhinoceros (*Rhinoceros unicornis*), milk composition, changes over lactation

Retention of solute and particle markers in the digestive tract of the Somali wild ass (*Equus africanus somaliensis*)

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In contrast to the domestic horse, whose digestive physiology has been thoroughly investigated, knowledge on the digestive physiology of wild equids is scarce. Comparisons between the domestic horse and the domestic donkey suggests that wild asses might achieve higher digestibilities. This could derive from longer retention times, or a greater difference in the mean retention time (MRT) of particles vs. fluid (the selectivity factor (SF)). Here, we measured MRT of a solute (fluid; MRT_{solute}) and a particle (< 2 mm; $MRT_{particle}$) marker in five captive male Somali wild asses (*Equus africanus somaliensis*) fed a diet of 95% grass hay. At a mean dry matter intake of 94 ±3 g $kg^{-0.75}$ d^{-1}, MRT_{solute} was 33.3 ±5.4 h and $MRT_{particle}$ 39.6 ±3.9 h, resulting in a SF of 1.21 ±0.14. For their food intake, Somali wild asses appeared to have slightly higher $MRT_{particle}$ than expected based on domestic equid data, in contrast to Grevy zebras (*Equus grevyi*), potentially indicating higher capacities of the digestive tract. However, considering data on domestic horses, donkeys, and zebra, there was no evident difference in the SF of wild equids compared to domestic ones. Together with an absence of reported anatomical differences in the digestive tract of wild and domestic equids, the data suggest a general similarity in the digestive physiology of equid species that contrasts with the diversity in the digestive physiology of ruminants, and that might be one contributing factor to a lack of sympatric, niche-differentiated equid species.

KEYWORDS: hindgut fermenter, passage, digestion, caecum, colon, gastrointestinal tract

Variation in amino acid composition of protein across and within prey species

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Although the literal translation of “carnivore” means “meat eater”, it is clear that carnivorous animals also ingest other parts of their prey in addition to muscle tissue; in some instances, organs such as the liver are often more preferred. In zoos, due to logistic and financial constraints, muscle meat is typically the main animal-derived dietary component for many carnivorous mammals such as felids and ursids. The origin (species) of the diets presented in zoos is another aspect that may affect the nutritional profile of prey compared to those consumed in the wild. Although amino acid deficiencies are typically not expected in zoo carnivores due to the high protein intakes, some points of concern can be raised when considering the non-protein functions of particular amino acids. For instance, glutamine is not considered a dietary essential amino acid, but the body of evidence on its role in immunity and gut health grows across species. Other examples can be given where amino acids might be needed in adequate amounts and ratios to ensure functions that go beyond the commonly excepted requirements, e.g. methionine as a methyldonor, histidine for antioxidant function, and the known example of taurine for bile acid formation.
A literature survey was performed to examine the variation in amino acid composition among body parts within the same species, as well as the variation of the same tissue(s) across species. These values were also compared with known amino acid requirements and suggested ideal ratios for various carnivores.
The amino acid composition of muscle meat, ranging from shrimp to beef, appears remarkably constant, with an average coefficient of variation (CV) of 7±4% (mean±SD) per amino acid. In contrast, CV among different parts of the cow averaged 12±5% per amino acid, significantly higher than the variation of muscle meat across species (P=0.001). This suggests that variation and/or optimization in carnivore diets might be best realised by providing different parts of the body, rather than solely variation in muscle meats from different species. Age of the prey is also an important contributor to variation when feeding muscle meat, because the proportion of collagen – a protein with particular amino acid composition – increases with age. The importance of this variation in feeding is demonstrated by comparing, for instance, the ratio of tryptophan to lysine requirement in cats (NRC) to the trp:lys ratio in the prey components: in all of the muscle meats, this ratio was much lower than the requirements ratio, whereas cow organs such as liver, kidney and brains provided a higher ratio. The drawback of this study is that amino acid digestibility was not taken into account, and data on the amino acid composition of, for instance, bone and skin, seem missing, but the preliminary results demonstrate that carnivores might need variation beyond muscle meat – irrespective of the prey species – to avoid amino acid imbalances. Efforts to compare the amino acid composition of wild prey versus livestock would still be worthwhile, as well as studies on health effects of dietary amino acid balances in captive carnivores.

KEYWORDS: *amino acids, tissues, carnivore*

The use of gas-test technique to predict digestibility and fermentation process in the large intestine of giraffes (*Giraffa camelopardalis reticulata*)

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The aim of the study was to evaluate the usefulness of the gas-test method to predict nutrient digestibility and fermentation processes that occur in the large intestine of giraffes (*Giraffa camelopardalis reticulata*).
The study was conducted on 2 female giraffes (4 and 5 years old). Giraffes were fed a standard diet consisting of vegetables and fruits (28% as fed), alfalfa hay (20%), browse (12%), and mixture of oatmeal, oat grain, granulate, linseed, dry beet pulp and soybeans (in total 40%). For 4 consecutive days, each component of the diet and refusals were weight and collected. Representative samples of faeces were collected for 5 consecutive days. Feaces collected over the first 4 days of collection period were frozen whereas fresh samples taken on day 5 were placed in a plastic container, filled with CO_2 and delivered immediately to the laboratory to carry out the gas-test. Dry matter, ash and acid insoluble ash were determined in feeds, refusals and feaces to determine in vivo organic matter digestibility. For the purpose of the gas-test, three types of inoculum were used: giraffe faeces (20 g), giraffe faeces (20 g) + cow's rumen fluid (40 ml) and cow's rumen fluid alone (40ml). Immediately after collecting, the rumen fluid was placed in vacuum flask filled with CO_2. The gas-test was carried out using the RFS Ankom Gas Production System (Ankom Technology, NY, USA). Samples of feaces were mixed with buffer (pH = 6.8) and then 125 ml of the inoculum was or was not mixed with 0.5 g of ground hay. This mixture was incubated for 24 hours in a weather bath with the function of shaking at 40°C (Elpin + Water bath shaker Type 357). The cumulative gas pressure (ΔP) was sent every 10 minutes to the computer for 24 hours and then converted to a volume unit (GP, ml). GP was used to predict *in vitro* organic matter digestibility (IVOMD) using an equation routinely used for ruminant species (IVOMD = 14.88 + 0.889 GP + 0.44 crude protein + 0.065 ash; crude protein and ash content in hay). Furthermore, volatile fatty acids (VFA) profiles of inoculum media was determined before and after incubation, by gas chromatography, as well as pH (pH / Ion Analyzer MA 235). Additionally, the impact of type of roughage (browse or alfalfa hay) and their fragmentation (0.1 and 0.7 cm) on the fermentation process were determined. 0.5 grams of browse and alfalfa ground to different sizes was added to samples of feaces-rumen fluid mixture.
The highest gas production was obtained with inoculum containing a mixture of rumen fluid from cow and faeces from giraffe. That could be effect of additional bacteria from feaces. Unfortunately giraffes feaces inoculum did not allow to determine gas production. Negative pressure was observed during the whole incubation of giraffes feaces inoculum.
The sizes of particles of feed (browse, alfalfa hay) affect the production of VFA and pH of inoculum media after fermentation (pH24). Results of this study suggest that gas-test can be used to determine the nutritional value of feeds for giraffes and fermentation processes in large intestine of giraffe.

KEYWORDS: giraffe, in vitro, fermentation, organic matter digestibility

A potentially cholesterol reducing diet is palatable and practical for cusimanse (*Crossarchus obscurus*)

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Meerkats and other mongoose species are known to have unusually high blood cholesterol levels in captivity; for meerkats the ZIMS reference mean is 9.52mmol/l (range 5.7-18.7) compared with a reported free-ranging mean of 5.93mmol/l (range 4.0-7.8). In some cases individual levels as high as 30.1mmol/l have been recorded in zoos, and such high levels have been associated with the death of individuals due to cholesterol granulomas in the calvarium. In other mammals, serum cholesterol levels can be reduced by diets that are low in saturated fats (SFAs), high in unsaturated fats (PUFAs) and high in fibre. Wild mongoose diets predominantly consist of invertebrates and small reptiles which are high in PUFAs and chitin, which may act in similar ways to fibre. High serum cholesterol levels in captive meerkats and mongooses are likely to be due, at least in part, to captive diets which tend to include mice, eggs, chicks and chopped beef or horse meat, all of which contain high levels of SFAs.
We trialled a diet for three cusimanse at Paignton Zoo Environmental Park that was formulated to be higher in PUFAs and lower in SFAs than their previous diet. We removed chicks and reduced the amount of mice, replacing them with small whole fish. We also increased the relative amount of locusts to mealworms to increase chitin content. The new diet was readily eaten by all the cusimanse, caused no significant changes in their behaviour or body condition, and was reported to be easy to provide by keepers. There was a very noticeable improvement in coat condition after 6 weeks of providing the new diet, presumably as a result of increased consumption of n-3 fatty acids. For reasons beyond our control we were not able to test serum cholesterol during this trial, however, we conclude that this diet is a practical, affordable and palatable option for further investigation into cholesterol management in this and similar species.

KEYWORDS: cholesterol, mongoose, fatty acids, coat condition

Carotenoid supplementation did not affect colouration in tufted puffins (*Fratercula cirrhata*) at Living Coasts

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Carotenoids cannot be synthesised by most animals so must be obtained from dietary sources. They have many functions in the body, including in the immune system and for antioxidant activity. In addition, they are the pigments responsible for many bright skin, hair and feather colours, including the bright red/orange colour of the bill, rosette and feet of puffins. Pigmentation is the lowest priority for carotenoid use in the body, so intensity of colouration can be a reliable indicator of condition and, therefore, important in mate selection. In birds carotenoids are passed from the mother into the egg yolk where they protect the developing chick from lipid peroxidation and enhance its immunity. Carotenoids may therefore be important for bird breeding success through affecting both the probability of mating and chick hatching and survival.

The tufted puffins at Living Coasts have had very low breeding success; since 2003 they have produced 94 eggs of which only 19 hatched and only 10 chicks survived longer than 30 days. No eggs have hatched since 2013 and no chicks have survived for longer than 30 days since 2011. One possible cause could be lack of carotenoids, as the adults have become noticeably less bright since their arrival in the collection in 2003. Therefore, we tested the effects of carotenoid supplementation using krill and a commercially available carotenoid supplement, RedRum gel, on their colour as one intervention to attempt to increase breeding success.

From November 2015 to February 2016 we took regular photographs of the puffins, together with a standard colour card for analysis by imageJ software, over a month in each of 4 consecutive conditions: normal diet, normal diet plus 2.3μg RedRum per bird per day, normal diet plus 112g krill per bird per day, and normal diet plus RedRum and krill. Samples of krill and RedRum gel were subjected to analysis for lutein and zeaxanthin (xanthophylls) and canthaxanthin and astaxanthin (keto-carotenes). There was no significant change in colour of bills and feet over the 4 month period. With the exception of astaxanthin (5.9mg/kg) the krill contained negligible amounts of carotenoids. The RedRum supplement contained higher levels of all the carotenoids: lutein (1180mg/kg), zeaxanthin (208mg/kg), canthaxanthin (7.21mg/kg) and astaxanthin (115mg/kg). In the 2016 breeding season the puffins produced three eggs of which one hatched but the chick died at a few days old due to yolk sac infection. Puffin bills contain β-carotene and other keto-carotenes at a total concentration of 304.7μg/mg. Puffin feet also contain these plus lutein and zeaxanthin at a total concentration of 657.7μg/mg. At the supplementation rates used our maximum total dose of carotenoids when fed RedRum and krill was 35μg per bird per day.

These results suggest that the supplementation rate was not high enough to cause an effect on colour. It is also unclear as to whether either supplement provides the appropriate carotenoid types required by puffins.

KEYWORDS: carotenoids, breeding success, colour, puffins

The husbandry impact of the Primate Nutrition Workshop, an EAZA Academy Recognised Course

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The Primate Nutrition Workshop is a three day course, recognised by the EAZA Academy, which we have so far delivered three times: twice at Paignton Zoo Environmental Park, UK (March 2014 and May 2016) and once at Rotterdam Zoo, the Netherlands (November 2015). Approximately 200 delegates have attended one of the workshops, representing 80 institutions. The workshop content includes information on natural diets and gastro-intestinal tracts, health issues in captive primates, nutritional requirements, how to formulate a diet to meet nutritional requirements, monitoring dietary intake, body condition and faecal scoring and what makes a good diet sheet. At the end of the workshop, each delegate is asked to list three changes they would like to make on returning to their institution. We have followed this up several months later with a survey to ask if these or other changes have been made, what impact they had on primate health, and - if intended changes were not made - what were the barriers.

Across the three workshops, intended changes included changing diet ingredients (36.1% of intended changes, of which reducing or removing fruit was the most common, 20.8%), monitoring diets (body condition scoring etc 19.7%), communicating what they had learnt to others (9.7%), performing nutrient analysis of diets (8.6%), improving diet sheets, (7.6%), investigating/improving UV provision (7.3%) and other changes to diet management and processes (11.1%).

Only the survey results from the first workshop have been analysed so far. The survey was completed by 87% of institutions that attended of which 92% had implemented at least one change. In total they had partially or completely achieved 107 changes, a mean of 4.1 changes per institution. Each change affected a mean of 7.6 primate species and 39 individual primates. Each individual primate may have been affected by more than one change, but the mean minimum number of individual primates (the most affected by any one change) impacted per collection was 49.2. By extrapolation, we could estimate that the diets of approximately 4000 individual primates have been impacted by the three workshops.

Of the collections that had implemented at least one change, 76% reported improved health or welfare of some or most animals, most frequently improved weight management and less aggression/tension within groups. Of these, 47% had specific data to support the improvements, whereas the others were based on normal daily observations of keepers. Negative effects on some individuals were reported by 20% of collections; these were nearly all either too much weight loss in some individuals or some aggression towards keepers during the transition to fruit-free diets. Only seven collections had investigated the impact of the changes on diet costs, four reported reduced costs, two no change and one increased costs, because previously they relied heavily on donated food.

The most common barriers to achieving changes were lack of time and lack of funds. Although during the workshop delegates predicted that resistance to change by colleagues (both senior and junior) would be a major barrier, this was only rarely reported in the follow up survey. Several respondents reported that the knowledge and confidence gained and respect for the EAZA Academy had helped overcome much of this resistance.

KEYWORDS: Primates, keeper training, nutrition, workshop, improved husbandry

Herbal nutraceuticals in animal nutrition and welfare

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The term “nutraceutical” is defined as a food or part of foods which help support an animal’s health and includes supplements. In this way nutraceuticals can also be used to describe those supplements which support mental health (i.e. relieve stress and anxiety), and impact an animal’s behaviour. Many feed supplements now boast behavioural improvement as a benefit of intake, alongside those marketed to encourage health and longevity.

The companion animal industry has led the way with the use of herbal nutraceuticals in animal feed supplements. This growing trend in herbal supplement popularity has now started to be reflected in the exotic animal feed market too.

Although herbal remedies have been traditionally been used by many different cultures over many centuries, there is still a lack of science and regulation over their use and even their efficacy. One area of ethical note is the impact of “calming” nutraceuticals and whether they produce an anxiolytic or sedative effect on various species of animal. As part of a wider study into herbal nutraceutical use, an online survey was publicised over winter 2015 to those in the veterinary field wishing to participate in the discussion on behavioural signs of sedation versus anxiety in captive mammals (mainly dogs and cats). Thirty-nine participants took part, related behaviours were grouped, and the Chi-Square test was used to analyse the results. Behaviours which were seen as significantly impacted (p<0.005) depending on whether a mammal was sedated or experiencing reduced anxiety included exploratory, play and social behaviours (X^2(1,n = 48) = 53.63, p=0.000). In contrast, sleep latency, sleep duration and rest behaviours were reported as having no significant difference (X^2(1,n = 37) = 0.748, p=0.387) when in either state.

These results highlight the difficulty in determining the impact of various nutraceuticals, specifically those which may impact behaviour, on an animal’s welfare. Furthermore they highlight the need for more scientific rigour in testing nutraceutical effects rather than relying on public testimonials for products alone.

KEYWORDS: Nutraceutical, supplement, herbal, health, anxiolytic, sedation, ethics.

A case of nutritional imbalance in Schalow's turaco (*Tauraco schalowi*) chicks

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The Schalow's turaco (*Tauraco schalowi*) is a frugivorous tree-dwelling bird of the family *Musophagidae.* It is commonly kept in captivity and is classified as *Least Concern* on the IUCN Red List. A breeding pair of Schalow's turaco, housed at Marwell Wildlife (UK) in a mixed aviary exhibit, successfully bred and hatched two chicks in the summer of 2016. However, at 10 days after hatching both chicks displayed clinical signs of leg perosis, presenting with bilateral hyperextended, rigid legs, which they were unable to bend back into their correct position. The parents abandoned these chicks at this time, possibly due to staff intervention in monitoring the chicks, and they subsequently died overnight.

Several factors were suggested to be the cause of the leg deformities, with nutritional deficiency highlighted as one possibility. Others included the nest shape and surface, inexperienced parents over-feeding the chicks, and an incorrect diet being fed to the chicks – for example by parents which had access to other bird species' diets.

A full dietary review of the nutritional requirements for breeding was conducted and advice sought from other collections and the species taxon advisory group (TAG). Behavioural observations were carried out using feed-site cameras to monitor what the parents were consuming.

The review resulted in trialling a different ratio of dietary components, including feeding out a smaller proportion of the T16 avian pellet and larger proportions of fruit and vegetables for all softbill species within the mixed aviary. Furthermore, video observations captured, somewhat surprisingly, footage of the turacos eating from an indoor floor-feeder containing ibis pellet and mince (provided for the carnivorous species kept in the mixed aviary).

The diet was changed and additionally, when the pair of turacos bred and lay again, they were prevented access to any other diet other than their own. Two chicks were reared to 23 days old when unfortunately they died due to non-related causes. Post-mortem investigations revealed no evidence of leg deformities, and these birds' legs had remained clinically normal throughout their lives.

The results reiterate several important factors within avian nutrition, including the correct balance of protein, calcium, phosphorus and other minerals in chick development; the need for scrutinising the analysis of "complete feeds" and adjusting diets with lifestyle changes; and the importance of behavioural monitoring in mixed species enclosures where multiple species-specific diets are fed. These observations also suggest preferred habitat territories and feeding practices seen in the wild may not always apply to a species when placed in captive environments.

KEYWORDS: avian nutrition, Schalow's Turaco, avian reproduction, perosis, diet

Rumen content stratification in giraffes

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Ruminants have traditionally been classified based on their feeding ecology as browsers, grazers or intermediate feeders. They can also be classified as either 'moose-type' or 'cattle-type' according to their digestive physiology. In this classification, 'moose-type' ruminants are characterised by having homogenous rumen contents, an even ruminal papillation pattern, a low throughput of rumen fluid and by feeding predominantly on browse. Contrarily, the 'cattle-types' have stratified rumen content and papillation, a high throughput of rumen fluid and include grass in their diet. The giraffe is a browse-eating ruminant and it has recently been documented that its digestive tract anatomy is similar to that of other 'moose-type' species. It was therefore hypothesised that the giraffe rumen content would be homogenous, as found in other browsing ruminants like moose (*Alces alces*) and roe deer (*Capreolus capreolus*). Browsing species, in particular the larger ones like giraffes, are notoriously difficult to feed in captivity – in part because the quantity and variety of browse needed to mimic what they eat in the wild is logistically impossible to provide for most zoos. Based on a number of indirect indicators, such as larger faecal particle sizes and a greater tooth wear reported previously in captive giraffes, it has been suggested that the digestive tract of the giraffe is not suited to efficiently handle traditional captive diets. Anecdotal evidence suggested that captive giraffes had a very different rumen papillation pattern compared to wild giraffes, which might indicate a change in the physical appearance of the rumen content towards being more stratified.
To investigate the effect of captive feeding on rumen content stratification, samples of dorsal and ventral rumen content were collected post mortem from 10 zoo giraffes and 27 boma-kept, wild-caught giraffes. In addition, samples of the rumen wall were collected from 3 standardised representative locations, to use papillation pattern as an indicator of content stratification over a longer period of time than the rumen content would reflect. Rumen content samples were oven-dried to constant weight to determine dry matter concentration. Results revealed no difference in the dry matter concentration between the dorsal and ventral part of the rumen in neither boma nor zoo giraffes, indicating unstratified rumen content as expected. The pattern of rumen papillation was determined by quantifying the number and area of papillae on a 1.5 x 1.5 cm piece of rumen wall and calculating the surface enlargement factor (SEF) of the papillae. Results of the papillae analysis supported the finding of unstratified rumen content in the giraffe, and, although not significant, indicated a less homogenous rumen content in captive giraffes.

KEYWORDS: Giraffa camelopardalis, ruminant feeding type, rumen papillae

Chemical composition of preys for insectivorous/carnivorous birds and reptiles

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A multitude of insectivorous birds and reptiles are kept in captivity as companion or zoo animals and are fed with different preys. The chemical composition of those preys is mainly unknown but necessary to calculate and assess the energy and nutrient supply of birds and reptiles. The aim of this study was to get an idea about chemical composition of different 'live food'.

Therefore, diverse kinds of feed insects and invertebrates, rats/mice, fowl and fish were bought from appropriate retailers. Preys were killed, washed, dried, ground and analysed using standard laboratory methods (i.e. proximate analysis, atom absorption spectrometry, ion exchange chromatography).

Chemical composition of different animals feed for pet animals:

Insects: Crude protein level of insects amounted on average 400-700 g/kg DM. Moreover, fat level varied between 15 (*Gryllodes sigillatus*) and 51 % in DM (*Galleria mellonella*). Insects show also a high variation in minerals. Chitin levels were between 2 and 30 % DM. Some reptiles may have chitinases and might thus be able to digest it.

Mice/Rats: Contain high amounts of protein and fat in DM. Besides, there is some variation found both between and within species.

Fowl: Bird products contain high amounts of CP (60 - 70 % in DM) and low fat levels. The Ca:P ratio can be considered as unproblematic.

Fish/Marine invertebrates: Most of these feedstuffs have low DM, but high protein contents. Moreover, some of them show higher fat levels (herring, anchovies). Mineral composition varies greatly among fish and invertebrates depending on the skeleton.

All in all the high fat ($\rightarrow$ energy) levels in some insects/animals has to be considered to avoid obesity (reptiles require less energy than mammals). Due to an imbalanced Ca:P ratio in insects, calcium should be added to avoid skeleton disorders. Special attention should be paid to animals (e.g. some birds like mynahs, lovebirds) which are sensitive to high amounts of iron (haemosiderosis).

KEYWORDS: birds, reptiles, insects, invertebrate

Hygienic quality of feedstuffs for birds (from granivores to fish eaters)

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Beside a well-balanced ration concerning energy and nutrient contents, a proper hygienic status of the offered feed is – due to diverse reasons (e.g. dust formation during feeding, ingestion of undesired germs) - a pre-condition in respect of animals' health. The occurrence of clinical symptoms (e.g. tympany, diarrhea) leads to the assumption of hygienic disorders of the offered feedstuffs (roughage, mixed feed and vegetables and fruits as well). At first the check of an infestation by pests (e.g. mites) should be recommended. Furthermore, it has to be considered that some of the moulds are able to produce mycotoxines that lead to negative effects on animal health and stress the immune system.

To get an idea of the hygienic status of feedstuffs for birds, 195 feedstuffs (e.g. seed mixtures, fruits etc.) sent in with a meaningful case history to the consulting service of the institute were analysed and assessed. The interpretation of the microbiological results were done with regard to benchmarks given in the current literature.

Within the sensory control, the parameters „texture“ (indicating moisture content of a feed) and „smell“ (mouldy or yeasty nuances?) gave first important clues. The occurrence of pests (mites, Psocoptera as indicator of a loading by moulds) was not a rare finding in microscopy. The culturally detected bacteria and moulds were differentiated between typical and spoilage-indicating germs.

Sometimes it is difficult to decide whether the reduced hygienic quality can be explained by the production conditions (that means in the factory) or by an improper storage of the feedstuffs by traders or owners. Furthermore, it might be assumed that the feeding technique (abrupt feed changes, insufficient exchange of the feeds) presents an etiological factor that leads to health problems in birds.

KEYWORDS: hygienic quality, germs, seed, fruit

Poisonous plants for zoo animals

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Intoxications do not belong to common health problems in zoo animals due to their controlled housing conditions. But according to the *Index veterinarius*, case reports exist about poisonings after ingestion of several plants. After intake of poisonous plants or plants with toxic ingredients, a cause and effect relationship has to be established between clinical symptoms and the ingested plant. Once the plant is identified the question arises about its toxicity. Data about LD_{50} rarely exist, as dose-effect-trials are not available. For this purpose case reports are used, allowing – if existing – a rough estimation of the toxicity.

It has to be considered though that the toxic level varies in dependence on several factors such as subtype, vegetative stage, fertilization, animal species as well as age. Housing conditions give important information for determining the presence of a poison-related health disorders (e.g., different botanical composition of accessible plants during indoor and outdoor housing).

Toxic plants are often ingested when the supply of fibre is insufficient (low amounts of hay, wood shaving litter, concentrates low in fibre) or out of boredom. Globalization of the crop trade is also accompanied with the ingestion of unknown and possible toxic plants. Exotic plants for planting of outdoor areas at home and gardens are used whose toxic levels are not or less known.

A distinction is made between kind (basic feed or concentrate or as well other products) and the origin (sampling, home-grown, purchased, commercial products) as part of the nutritional anamnesis.

Timely correspondence between occurrence (free-run at home, offering of sampled herbs) and the appearance of clinical symptoms is very meaningful. Sudden death without previous clinical symptoms and a tight time sequence coupled with a feed change both lead to the suspicion of an intoxication by plants.

In cases of severe clinical symptoms and sudden death of zoo animals, an intoxication due to the ingestion of poisonous plants should be excluded. The assumption is further supported when animals showed no or only short-term clinical symptoms and infections were excluded. In those cases changes of the environment (outdoor area) or of feeding (new batch, offering of sampled „herbs“) should be srutinized critically.

KEYWORDS: poisonous plants, zoo animal, intoxication

Feedstuffs for carps and koi fish – a comparison with regard to nutrient composition and requirements

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In recent years the keeping of koi fish has gained popularity in Germany. Traders specia lized in koi fish offer affordable individuals, whereas the feedstuffs for these animals usually are higher-priced products. Although predominantly privately owned, koi fish might be fed need-based with standard feedstuffs for carps in aquaculture, as they belong to the family of the cyprinids. Therefore, the aim of the study was to compare carp and koi fish feedstuffs regarding the composition of nutrients and hence the fulfilment of nutrients' requirements.

Commercial feedstuffs for semi-intensive and intensive rearing of carps (n=10) and koi fish feed (no winter feed, n=10) were randomly selected and analysed (crude nutrients, amino acids, digestible energy).
The crude nutrient contents (CP, CL, crude fibre [CF], ash and nitrogen free extracts) of the selected feedstuffs for carp and koi fish vary widely within the same group, indicating a representative selection of each type. However, the analysis of variance revealed no differences ($P>0.05$) between carp and koi fish feedstuffs within the same crude nutrient. Concerning the declared values of CP, CL, CF and ash, in 10 feedstuffs (4 for carp, 6 for koi fish) deviations above or below the declared contents for one or more nutrient within the same feedstuff were analysed according to the directive 767/2009/EG for allowed tolerances in mixed feed.

In both feed types the total content of essential AA exceeded the requirement of 115 g/kg dry matter (DM) with 172 g/kg DM in carp feed and 157 g/kg DM in koi fish feed. However, regarding single AA, in 4 feedstuffs of carp feed the contents of lysine, methionine and threonine did not meet the animals' demands, whereas in koi fish feed the contents of lysine, phenylalanine and valine did not fulfil the requirements in any of the tested feedstuffs. In accordance to these findings, differences ($P<0.05$) for lysine, methionine, phenylalanine, threonine, valine and as well tyrosine and histidine were found between feed types.

The recommended DE/CP ratio of 0.4-0.5 MJ DE/g CP was reached in 6 carp and 5 koi fish feed samples, respectively, but generally DE/CP ratios did not differ ($P>0.05$) between feed types. For the six most important quality parameters (CP, sum of essential AA, DE/CP, CL, starch and soluble P) an overall evaluation was carried out. According to this assessment, a feed for intensive aquaculture carp rearing, a feed for intensive rearing of koi fish and another feed for intensive carp rearing were ranked in first, second and third place, respectively, whereas 2 other koi fish feedstuffs were among the top 10 placed in the ranking.

Considering the nutrient demands for cyprinids, the carp feedstuffs show a more favourable composition with on average higher CL contents and a better AA profile as well as DE/CP ratio. However, the energy content in protein-rich carp and koi fish feed is considered to be too low, which might lead to excessive nitrogen excretions. In general, differences between analysed parameters were low, so that from the nutritional point of view commercial carp feedstuffs for aquaculture might be used for koi fish in accordance with the need-based nutrient composition. The higher ($P<0.05$) average prices (€ ct) per g CP and MJ gross energy, respectively, of koi fish feed are therefore not justified.

KEYWORDS: fish, nutrients, koi, carp, diet design

Nutritional related obstipations in bearded dragons

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In recent years the keeping of reptiles (more than 5000 species) enjoys more and more popularity. Beside turtles and snakes the saurians – especially bearded dragons - belong to the numerously kept pets. In the wild, bearded dragons hunt rodents, frogs, young birds, insects and smaller reptiles, but ingest also vegetables (up to 50 % of the total ration); young animals eat mainly products of animal origin. Concrete data regarding energy and nutrient requirements are absent. Therefore, in these species nutritional disorders still occur that belong to the past in other animals. With this study some of these problems regarding feed choice, feeding technique and nutrient supply are described.

KEYWORDS: reptile, diet composition, obstipation

Investigation on feeding seed mixtures vs. extruded diets in parrots

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A lot of different feedstuffs are available for parrot nutrition. Seed mixtures are one of them and are frequently fed. In recent years extruded complete diets have been formulated to avoid selective ingestion behaviour of parrots with associated risks. Additionally, this kind of feedstuff is characterized by a homogenous formulation with a chemical composition which meets the requirements of the bird. In this study the palatability of the offered diets and the ingestion behaviour (duration, rhythm, amount of food intake) was investigated. Furthermore, the digestibility of extruded diets in comparison with a commercial seed mixture was determined.

The conversion of the parrots from seed mixtures to formulated diets without adaption period caused no particular problems or mean body mass losses. The offer of the seed mixtures caused a biphasic feed intake whereas the extruded diets were consumed continuously throughout the day. Offering extruded diets reduced the average time for feed intake (measured in minutes per grams feed), but due to the lower energy density and a higher consumption, the total time required for feed intake was almost the same.

The daily dry matter intake while offering extruded diets averaged 21.0 gm in amazons (*Amazona aestiva, Amazona amazonica*), 26.1 gm in African greys (*Psittacus erithacus erithacus*) and 17.0 gm dry matter in cockatoos (*Cacatua galerita, Cacatua goffini*).

The digestibility of organic matter varied between 73 and 87% (compared to an average of 78% while offering fatty seeds and 87% while ingesting components rich in carbohydrates).

KEYWORDS: parrot, seed mix, extruded diet, complete diet

NOTES