THE EUROPEAN ASSOCIATION OF ZOOS AND AQUARIA

EAZA Nutrition Group News
July 2020

FOREWORD

Anouk Fens, Nutritionist, Apenheul Primate Park, the Netherlands, and Chair EAZA Nutrition Group

Organised by the EAZA Nutrition Group (ENG), the 10th European Zoo Nutrition Conference took place at Marwell Zoo (UK) in January 2019. The biennial conference was a huge success, attended by more than 160 delegates from 30 countries including USA, Japan, Singapore and Australia. The conference programme promised to be diverse, including talks on the importance of vitamin D, as presented by keynote speaker Dr Susan Lanham-New, several talks on the importance of feeding browse to our herbivores, and a number of presentations by well-known members of the zoo nutrition community, including former Chair of the ENG Andrea Fidgett. This special nutrition-themed issue of *Zooquaria* is based on papers and posters presented at Marwell and contains a wide range of topics demonstrating the importance and relevance of animal nutrition to zoos.

Organising a conference and publishing this special nutrition issue requires the help of many individuals and organisations. I would like to express my gratitude to the organising committee and everyone involved at Marwell for their efforts in running a very successful conference. Special mention must go to Joeke Nijboer and Kristina Johansen for all their work in putting together this issue, as well as Marcus Clauss and Amy Plowman, who were responsible for reviewing the papers published in this issue. I would like to thank all authors who contributed to this issue by submitting their articles. Finally, this issue would not have been published without financial support provided by sponsorship. I would like to thank Brogaarden, Granovit Zoofeed, Kasper Faunafood, Kiezebrink International BV and St Laurent for their support.

The ENG aims to improve the understanding of zoo animal nutrition in several ways. These include the organisation of the biennial conferences as well as sourcing and distributing relevant materials, updating the EAZA website and ENG Facebook page and liaising with TAGs and zoo nutrition experts across Europe to ensure good communication and collaborations. You will find more information on the ENG, its aims and possibilities for membership on the EAZA public website.

Finally, I would like to take the opportunity to mention the next European Nutrition Conference, which unfortunately had to be cancelled, but currently a different format is being proposed. Please visit the Events page on the EAZA website to keep up to date with the latest information.

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CONTENTS


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Primates
Herbivores
Carnivores
Birds
Fish-Eaters
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FOOD FOR THOUGHT

THE 2019 EUROPEAN ZOO NUTRITION CONFERENCE AT MARWELL ZOO REVISITED TOPICS THAT ARE VITAL TO THE HEALTH AND WELFARE OF THE ANIMALS IN OUR CARE

Anouk Fens, Nutritionist, Apenheul Primate Park, the Netherlands, and Chair EAZA Nutrition Group

Every two years, the European Zoo Nutrition Conference brings together zoo nutritionists, keepers, veterinarians, researchers and feed companies from across the globe to share their knowledge and experience. The 10th European Zoo Nutrition Conference was organised by the EAZA Nutrition Group in January 2019, hosted by Marwell Zoo, UK. The second ever nutrition conference was due to be held at Marwell Zoo back in 2001, but was cancelled at the last minute due to foot and mouth disease. Although it took 18 years to bring the conference back to this venue, the effort was worth it, as this was the biggest European Zoo Nutrition Conference yet, attended by 161 delegates from more than 30 countries, including several attendees from institutions in Japan, Australia and the USA.

Prior to the conference, delegates could attend an EAZA Academy Workshop covering the topic of 'Meat and fish quality, nutrition and feed presentation'. The workshop was facilitated by Richard Chivers (Food Safety Southwest), Dr Len Lipman (Utrecht University), Professor Dr Annette Liesegang (University of Zurich) and Professor Dr Marcus Clauss (University of Zurich). It combined theoretical information on fish and meat quality and nutrition, and practical elements on assessing fish and meat quality. The workshop was followed by an enjoyable icebreaker evening in the nearby Marwell Hotel, which allowed colleagues from around the world to engage with each other once more.

The programme for the three-day conference was mostly dedicated to scientific sessions, but also contained poster sessions and sponsor pitches, a zoo visit and a conference dinner. The conference also provided an opportunity for delegates to interact with sponsors from the commercial feed industry. After the welcome by Dr Will Justice, Head of Plants and Animal Management at Marwell Zoo, the first conference day was opened by David Williams-Mitchell, EAZA's Director of Communications and Membership, who delivered an update from EAZA. The day then kicked off with two opening keynote talks addressing the role of vitamin D in health and nutrition. Professor Susan Lanham-New (Surrey University) explained the challenges of vitamin D supplementation in human nutrition, and Frances Baines (UV Guide UK) translated theory into practice by talking about the use of UVB lights and full-spectrum lighting solutions.

In general, session topics were dedicated to different taxa, including mammal, reptile and bird nutrition. Within mammal nutrition, obesity management in equid species was discussed, along with fruit-free diets for primates, body condition scores (BCS) in elephants and nutrition for geriatric zoo animals. Attention was paid to reptile and bird nutrition as well; talks included challenges in raptor nutrition, digestive tract differences between Old World vultures, feeding regimes in lesser flamingos and BCS of tortoises.

We were happy to welcome a new topic to the programme, namely browse quality and storage. The provision of browse is becoming more important within the diets of browsing herbivores. However, many zoological institutions face challenges in storage and collection of sufficient quantities of browse, often only seasonally available. In this session, results were presented on the effects of frozen storage on the chemical composition and fermentability of browse. Invited speaker Sven Seiffert (Zoological Society of London) explained the challenges and lessons learned during 10 years of browse provision.

Other highlights were the two talks given by nutrition colleagues from overseas: Dr Andrea Fidgett from San Diego Zoo and Shannon Livingston from Disney Animal Kingdom. Their talks gave us a look inside the 'kitchen' of American zoos, in terms of their history, current challenges and future steps within animal nutrition. Recently, Andrea Fidgett stepped down as Chair of the ENG and we were delighted to welcome her back to the conference.

During the zoo visit, several workshop stations were spread throughout the zoo, where information was presented on specific zoo animal nutrition topics, such as body condition scoring, forage sampling, faecal consistency scoring, feeding anatomy and dentition and conducting a diet change. Delegates also had an opportunity to explore the zoo's collection via guided tours.

The conference also presented an opportunity for students to share the results of their research by means of posters and pitches. There were more than 15 scientific posters on show covering a huge range of topics and taxa, showcasing some very interesting research and results. All delegates were asked to vote for the best poster. 'Browse preference in bonobos' by Dr Sarah Depauw and others won with a convincing majority.

A huge thank you is owed to the organising committee, which consisted of members of the ENG, EAZA Executive Office and Marwell Zoo, for putting together a wonderful conference, including a very interesting series of talks and posters. In addition, the ENG was very successful at attracting sponsorship for the conference. Thank you to sponsors Kaspar Faunafood, Granovit, Kiezebrink International BV, Lucerne for Browsers – Itchen Valley, Mazuri Zoofoods, St Laurent, Versele-Laga NV and Zooprofis for their support and contribution to the success of the conference.

CONFERENCE WISDOM

THE FOLLOWING ABSTRACTS ARE JUST A FEW EXAMPLES OF THE MANY INFORMATIVE AND INSPIRING TALKS THAT WERE GIVEN DURING THE 10TH EUROPEAN ZOO NUTRITION CONFERENCE, HELD AT MARWELL ZOO IN JANUARY 2019

Practical raptor nutrition: how, why and when it goes wrong and how to avoid the pitfalls

Neil Forbes, Great Western Exotic Vets, Wiltshire, UK

Diseases of raptors in human care related to the food they have consumed are many and varied. This paper highlights the basic principles of raptor nutrition, together with the risks associated with ingestion of foods of varying provenance. Feeding in special circumstances will be addressed.

Nutrition must be provided so as to ensure freedom 'from hunger, thirst by ready access to fresh water and a diet to maintain full health and vigour.' The risks associated with certain foods must be appreciated and assessed. Supplements, probiotics, vitamins and minerals may be necessary at times of stress and increased metabolic demand (growing, training, breeding, moulting or following illness). Infectious diseases are less likely if mammalian rather than avian food is provided. Each raptor species has evolved to fill an ecological niche. In the absence of detailed nutritional data the dietary needs are most likely to be met by feeding a diet approximating to that which would be taken, under ideal conditions, in the wild (Kirkwood, 1980).

The maintenance energy requirement of raptors is 110Kcal/kg 0.75/day. The daily intake as a percentage of bodyweight is as follows:

- 100g bird – 25%
- 700g bird – 15%
- 1,200g bird – 10.7%
- 4,000g bird – 6.25%
- 7,000g bird – 3.5%

It can be seen that larger birds eat more food but require a significantly smaller percentage of their body mass as daily food intake. The consumption of a prey animal by a raptor involves the bird eating casting (fur and feather), muscle, bone, viscera and the prey's gut content. In supplying food to captive birds, all these elements should be considered.

Foods available for feeding to captive raptors include day-old chick (doc), 'grown-ons' (chickens or turkeys of several weeks old), quail, rabbit, various rodents, beef, venison, lamb and horsemeat. More than 50% of UK raptor keepers feed only day-old chicks. Any diet limited to one source is likely to be unsatisfactory. There are marked interspecies differences in nutritional requirement.

Source and storage of food

Wholesomeness, source, method of killing, freezing and storage must be appropriate. Raptor food species receiving *ante mortem* medication must have an appropriate withdrawal period. Once killed, any food must be quickly and effectively frozen to avoid any bacterial proliferation. Frozen food in transit must not defrost and frozen storage must not exceed three months. Foods should be defrosted (at 4-8ºC), to avoid bacterial proliferation. The potential risks of zoonotic infections should always be considered when handling raptors or their food.

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Survey of feeding practices and nutrition of captive Aldabra giant tortoise (*Geochelone gigantea*) populations in EAZA institutions

Daniel Harrold, Amy Plowman & Luke Harding, Wild Planet Trust, Paignton Zoo Environmental Park, UK

Zoo animal nutrition is an ever-developing field within conservation biology research and is crucially important for the longevity of often-threatened taxa housed within institutions. Herpetological nutrition, at the genus or species level at least, remains in its infancy. *Ex situ* collections should strive to

formulate species-specific diets for as many reptile and amphibian taxa as possible to improve *ex situ* health and welfare. Aldabra giant tortoises (*Geochelone gigantea*) are common and charismatic reptiles and are kept in many European collections. There is sparse published literature on zoo nutrition for these giants compared to the closely related Galapagos tortoises (*Chelonoidis spp*.).

A dietary survey was sent to 44 EAZA institutions with *G. gigantea* registered in their living collections on ZIMS (Species360). Responses from 18 collections (41%) from seven nations were received, accounting for 92 tortoises. Survey questions ranged from population demographics to basic husbandry practices, which then focused on modes of feeding, health and breeding success. Quantitative data was plotted graphically to evaluate common trends.

Average population size was 4.84 individuals with a sex ratio of 1:1 and a mean age of 28.3 years (range nine to 157 years). Seventy-eight per cent of institutions report no current health problems. Sixty-one per cent of collections highlight a lack of mating and breeding, but this is unremarkable as 54% of individuals are under the age of 20 years and so are not sexually mature. Thirty-nine per cent of collections do not vary their diet sheets seasonally; however, 28% reduce the amount of fruits and vegetables provided due to restrictions to access foodstuffs in winter months. Favoured feed items included domestic weeds, endive, tomato, carrot and bell pepper with fennel, carrot, courgette and leek commonly left uneaten. Over half (56%) confirmed the use of dietary supplementation; the most common products used included Nutrobal, cuttlefish bones and calcium carbonate powder.

The results demonstrate some clear disparity between feeding regimes, quantities and feed items among collections, highlighting the need for increased collaboration and synthesis of currently implemented feeding practices. There were few physiological conditions noted, which provides reassurance that these tortoises are adequately maintained with the provided diets. The poor fecundity rate and hatching success, along with large dietary variation within European collections, may mean that this species will greatly benefit from published best practice guidelines. Increased data-sharing and collaboration between institutions should be promoted for this and other related species.

Nutritional analysis on aardvarks in human care and separation solution of termant using emulsifiers

Hannah Davies, Jo Bond & Kerry Hunt, University Centre Sparsholt, UK

FERNANDO FLORES VIA FLICKR

The aardvark (*Orycteropus afer*) is a myrmecophagous species. In the wild, termites make up the majority of the aardvark's diet. In addition, this species feeds on locusts, ants, small mammals and vegetable matter. In human care, a complete diet called Termant is often used, which was developed to meet the nutritional requirements of captive myrmecophagous species. This diet is fed to giant anteaters (*Myrmecophaga tridactyla*), pangolins, armadillos and aardvarks. Whilst the diet has been marketed as a complete diet, issues documented with the use of this diet include softer faeces in zoo-kept ant-eating mammals, and a low water-holding capacity, so that after preparing a slurry, water rises to the top of the bowl and solids sediment. This study looked at the impact of various emulsifiers on the separation time of Termant as well as the nutritional effect of adding these ingredients.

Emulsifiers are thickening agents which are used daily in cooking a variety of foods, such as soups, sauces and desserts. Xanthan gum, guar gum and gelatine were used for this study. Xanthan gum is developed by fermenting corn sugar, which creates a microbial polysaccharide. Guar gum is created from guar beans. Gelatine is produced from animal collagen. Four feed mixtures were produced: Termant alone, Termant and xanthan gum, Termant and guar gum, and Termant and gelatine, all at a ratio of 200:1. In addition to the four mixtures, four different ratios of water dilution were tested to determine the ideal amount needed for producing a stable Termant slurry.

A ratio of 200:1 Termant to emulsifier was utilised for each emulsifier, using 15g of Termant with 0.075g of emulsifier. Four different dilutions were also used to see whether this had an impact; these were 2ml of water per gram of Termant, 2.125ml/g, 2.25ml/g and 2.5ml/g. Time-lapse cameras on an iPad were used to record the separation over a six-hour period. The speed of separation was measured, as was the amount of separation in millimetres.

The results suggest there is a significant difference ($p<0.05$) in the amount of separation at every dilution with the use of the emulsifiers, with the best two mixtures being Termant and xanthan gum and Termant and guar gum at a dilution of 2ml/g. Both of these mixtures also still met the nutritional requirements of captive aardvark. However, palatability tests need to be performed to see if these mixtures will actually be consumed, and their consequence for faeces consistency need to be assessed.

Further information
All conference abstracts can be found on the EAZA website at: https://www.eaza.net/assets/Uploads/Events/ENC19/Abstract-book-EZNC19.pdf

MAKING LIGHT WORK

IF ALL OF OUR ANIMALS NEED FULL-SPECTRUM LIGHTING, HOW CAN WE PROVIDE IT?

Frances M. Baines, UV Guide UK

A nutrient is defined as a substance or ingredient that is ingested or absorbed that promotes growth, provides energy and maintains life. So it makes sense that this does not exclude full-spectrum lighting, as this is certainly absorbed – by the skin, over the entire body of any animal in daylight.

VITAMIN D3

Full-spectrum lighting, including UVB, is most often recommended to enable vitamin D3 synthesis in the skin. Vitamin D3 has a vital endocrine function – maintaining calcium homeostasis – but recent research has revealed it as a potent regulator of gene transcription, too, with particularly important effects on the immune system.

We still know little about the actual daily vitamin D3 requirements of exotic animals. Very few natural diets contain more than traces of vitamin D3; it seems likely that many wild vertebrates rely upon cutaneous physiological and behavioural adaptations to ensure that ambient UVB levels in the microhabitat of each species are sufficient for optimal D3 production.

ULTRAVIOLET

UVB has direct local effects on skin. An excess is harmful and can cause significant damage to living skin cells, but exposure to levels naturally experienced by the species in question is beneficial. It is a disinfectant. It modulates the skin's immune system, stimulates lymphocytes and melanocytes and enables beta-endorphin synthesis. UVA stimulates nitric oxide production in the skin; this acts as a vasodilator, improving skin circulation, and also protects cells against UV damage. UVA is also part of the visible spectrum to most reptiles and amphibians, a wide range of bird species and a surprising number of mammals. Its provision is therefore psychologically important, enabling full colour vision in these animals.

VISIBLE LIGHT

Visible light is often regarded as necessary purely for vision; this could not be further from the truth. Non-visual perception of light levels has far-reaching effects on the brain via a neuro-endocrine network. This sets circadian rhythms and controls the levels of neurotransmitters and pituitary hormones, which affect most physiological processes, including growth, reproduction and responses to stress. Natural sunlight may reach over 100,000 lux; typical indoor lighting may be two orders of magnitude below this level. Irradiance levels matter.

SHORT-WAVELENGTH INFRA-RED (IR-A)

Sunlight contains one further 'nutrient' that rarely receives attention – short-wavelength infra-red. This, unlike longer wavelengths emitted by heat panels and radiators, penetrates the skin to significant depths. It warms effectively without overheating the skin surface. It also has biological activity, upregulating more than 100 genes, stimulating cell growth and the immune system, promoting wound healing and protecting against UV damage.

FULL-SPECTRUM LIGHTING FOR ALL?

We now have extremely good, readily available full-spectrum lighting solutions for almost anything, from a tiny dartfrog vivarium to a huge primate enclosure. The questions we need to answer now are 'How much light does this animal need?' and 'How can we supply it?'

HOW MUCH LIGHT DOES THIS ANIMAL NEED?

Species vary widely in their native habitats, and hence their lighting

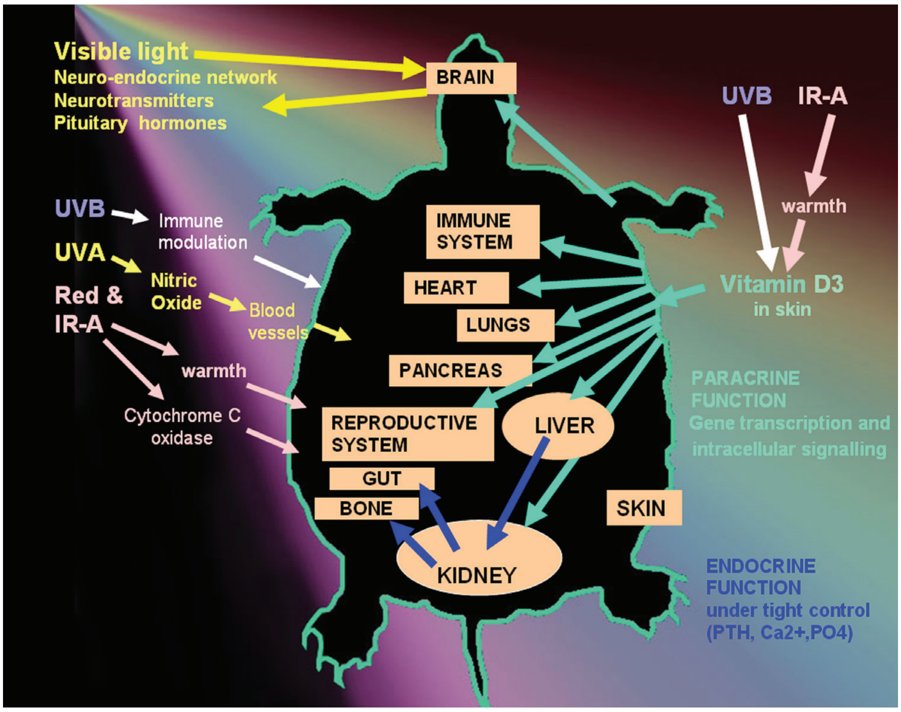

Figure 1: The physiological effect of sunlight.

Ferguson Zone		Microhabitat	Suggested UV range	
	Zone 1	Shade dwellers; crepuscular; nocturnal	UVI from zero in shade up to max 0.7 - 1	
	Zone 2	Dwellers in dappled sunlight / forest edge	UVI from zero in shade up to max 1 - 3	
	Zone 3	Sun-loving and shade-seeking	UVI from zero in shade up to max 3 - 7	
	Zone 4	Full sun all day	UVI from zero in shade up to max 4.5 - 8	

Figure 2: Interpreting the 'Ferguson zones' as microhabitats of suitable UV index ranges for all taxa.

requirements in human care also vary. Exposure to light depends upon both the microhabitat and the behaviour of the animal within it. Very little research has been done on this, almost all of it in regard to UV. However, similar microhabitats will have similar UV levels. Ferguson *et al*. (2010) identified UV ranges typical of four basic microhabitats occupied by different species of reptile. These four ranges or 'Ferguson Zones' have been used to estimate suitable UV levels for reptiles in human care (the BIAZA RAWG UV-Tool – Baines *et al*., 2016). Since these microhabitats are common to almost all terrestrial species, it seems reasonable to experiment with them as guidelines for other taxa, as well.

For a more detailed discussion on this, see the December 2015 edition of *Zooquaria*.

PROVIDING FULL-SPECTRUM LIGHTING INDOORS

When ambient temperatures are appropriate, access to outdoor enclosures can provide real benefit. Indoors, UV-transmitting glass (with up to 50% UVB transmission) and UV-transmitting acrylics (up to 80% UVB transmission) can be used for skylights and windows. In northern latitudes, however, adequate levels of UVB for tropical and sub-tropical species may be available only for short periods in summer. Full-spectrum lighting indoors inevitably requires specialist UVB lamps combined with very bright 'daylight' lamps for visible light, plus incandescent lamps or short-wavelength infra-red heaters for IR-A.

The aim is always to create a photogradient, with a 'patch of sunlight' large enough for the occupant to walk into on one side of the enclosure and shade and shelter on the other side.

LIGHTING FOR SMALL ENCLOSURES

In vivariums, terrariums and small enclosures, simple, old-fashioned incandescent lamps and halogen lamps are an excellent source of visible light and IR-A, plus small amounts of UVA. 'Spot' basking bulbs commonly sold for reptiles do not create wide enough beams, but 'flood' bulbs such as PAR38 and reflectors with frosted front glass and at least 30° beam width are ideal, and can be controlled using dimming thermostats. Additional visible light can be provided by 'daylight' fluorescent tubes or compact lamps, by small non-UVB metal halide lamps or by 'white light' LEDs – although LEDs provide no UVA.

UVB lamps for small enclosures come in three basic types:

1 **Standard (T8) UVB fluorescent tubes and compact fluorescent lamps.** These typically have a low UVB output and an unfocused beam. They can be used to create small zones of low-level UV, with a UV Index up to approximately 1.0 (similar to that found in shade outdoors), thus suitable for use with animals in Ferguson Zones 1 and 2. They need to be combined with bright visible light and infra-red to complete the spectrum.

2 **T5 High Output (T5-HO) UVB fluorescent tubes.** These typically have a much higher UVB output, and a more focused beam when used in a fixture with an aluminium reflector. These can be used to create zones of UVB at 'sunlight' levels, up to around UVI 7.0 – although a maximum around UVI 3–5 at the closest point to the lamp is normally sufficient. They are therefore suitable for use with animals in Ferguson Zones 3 and 4.

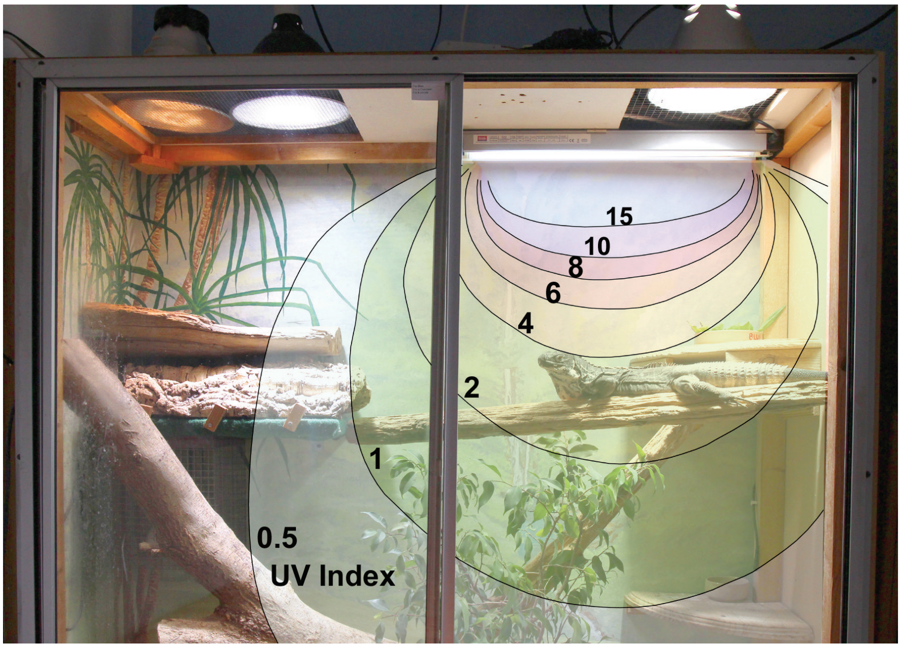

Figure 3: Lighting for a small enclosure using a T5-HO 12% UVB tube in combination with incandescent and non-UVB metal halide lamps. The UV Index iso-irradiance chart for this lamp is overlaid to 'visualise' the UV beam.

These also need to be combined with bright visible light and infra-red to complete the spectrum.

3 **Mercury vapour UVB lamps and UVB metal halide lamps.** These are often sold as 'all-in-one' lamps, providing UV, visible light and IR-A all together. Brands vary widely in their UVB output, and in the width of the beam. Narrow 'spot' beams, some with very high UV in the centre of the beam, should be avoided, but wide 'flood' lamps can be useful. However, these lamps cannot be thermostatically controlled, which is a major disadvantage in small enclosures.

LIGHTING FOR LARGE ENCLOSURES

Providing large, walk-in basking zones and artificial 'patches of sunlight' for large animals in room-sized enclosures and aviaries requires a different approach.

IR-A can be very effectively provided using short-wavelength infra-red 'patio heaters' mounted on a wall or ceiling. These are widely available in 1.5kW and 2kW versions.

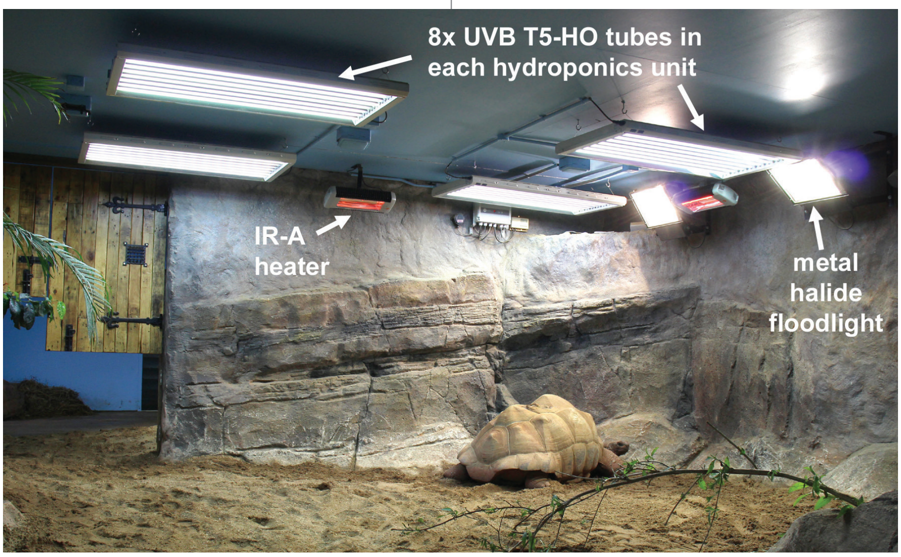

Figure 4: A group of four 8-tube hydroponics fixtures holding 12% UVB tubes, combined with patio IR-A heaters and metal halide floodlights, used to create a 'patch of sunlight' with UV Index 3–4 across an area 5m wide, for a group of Aldabra giant tortoises at Paignton Zoo, UK.

High quality 'daylight' metal halide floodlamps of the type used to illuminate sports halls and floodlight buildings are probably the best indoor substitute for the visible and UVA parts of the solar spectrum. Powerful LED floodlights can also be used, but lack UVA.

As regards UVB, to date only one type of lamp has proven able to illuminate large enough areas with 'sunlight' levels of UVB: the T5-HO UVB fluorescent tube. Multi-tube T5-HO hydroponics fixtures are proving successful in UK zoos in large enclosures for reptiles, amphibians, primates and birds. These are available in a wide range of sizes, the largest taking eight 120cm, 54-watt T5-HO tubes. When T5-HO UVB tubes are installed in these reflective fixtures, the units can be suspended up to 2m above the animals.

A NOTE OF CAUTION

All UV guidelines to date are just estimates, and the use of UV with mammals and birds is still experimental. It is vital to monitor the levels of UV and the animals' responses. Albino and hypomelanistic specimens of any species are likely to need much-reduced exposure levels as their skin and eyes are often more sensitive to UV and visible light.

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A DIET FOR INSECTIVORES

MEETING THE NUTRITIONAL REQUIREMENTS OF INSECTIVOROUS MAMMAL SPECIES

Kerry Hunt, Hannah Davies, Clover Hills and Jo Bond, University Centre Sparsholt, UK

In recent years the welfare of captive myrmecophagous species has been of increasing research interest. Practically meeting the nutritional requirements of these species has been challenging, as there is a range of health issues associated with current feeding practices (Clark *et al*., 2016). By reviewing current literature and considering the diets provided to several myrmecophage species held in human care, this study hopes to highlight some of the current feeding practices in industry and consider their effectiveness.

Clark *et al*. (2016) identified that giant anteaters (*Myrmechophaga tridactyla*) in UK collections had loose stools, tying in with earlier research that identified liquid faeces, vitamin K deficiencies and cardiomyopathy (Valdes & Brenes Soto, 2012). Valdes & Brenes Soto (2012) suggested that it is suitable to use domestic dog (*Canis lupus familiaris*) and cat (*Felis catus*) diets as a model when developing and evaluating anteater diets. Historically, anteaters were fed a gruel diet mix which contained, amongst other ingredients, milk products, raw meat, eggs, dog food and fruit (Gillespie, 2003). More recently a range of commercial complete diets have been developed for insectivorous mammal species, including Mazuri's Termant and DK Zoological's Insectivore diet. These are most commonly powders that are mixed with water to create a paste. Bissell (2017) highlighted that when given choice over their diet, there was a difference in the nutritional content of the diet that the animals selected; more generalist species such as the armadillo selected a carbohydrate-rich diet when compared with more specialist ant- and termite-eating species, suggesting that a species-specific approach would be beneficial in diet development.

To date there have been only a couple of studies on the wild diet of insectivorous mammal species. One study on pangolin diets found that Temminck's pangolin (*Smutsia temminickii*) predominantly consumed four different ant species and one species of termite (Pietersen *et al*., 2015). However, this was not correlated to the abundance of these species in the environment, suggesting that the pangolins were actively selecting specific species. In another study, Oyarzun *et al*. (1996) focused on the diets of wild tamandua (*Tamandua tetradactyla*), suggesting that individuals selected different diets, with one individual preferring ants (69% of diet) and another preferring worker termites (77% of diet).

An increasing number of studies has focused on the nutritional content of invertebrates. Some of these focused on animal diets (Finke & Oonincx, 2014), but the majority focused on invertebrate species as a food source for humans. One large-scale study on human nutrition (Rumpold & Schlüter, 2013) has provided average data for the most commonly identified genera consumed by myrmecophage species.

Oyarzun *et al*. (1996) undertook proximate analysis of the stomach contents of wild tamandua and identified that on average the stomach contents were 51% protein, 11% fat, 3% acid detergent fibre and 14% ash. This gives some idea of the nutrient intake in termite-and ant-eating species.

AARDVARK NUTRITIONAL ANALYSIS

Data was collected from five of the six collections in the UK that housed aardvarks in 2017. This was analysed for dietary components as well as nutritional content.

Figure 1 shows that all of the collections used Termant as the base for their diets; however, the amount of Termant provided per aardvark varies considerably between collections, from 325g to 1kg per individual. Collections also

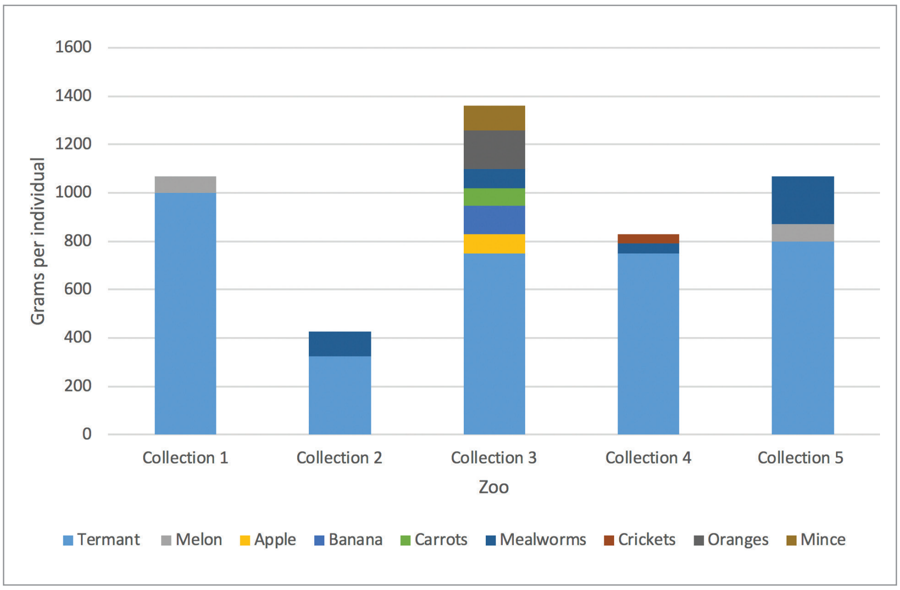

Figure 1: The aardvark diets of the five collections that provided diet sheets.

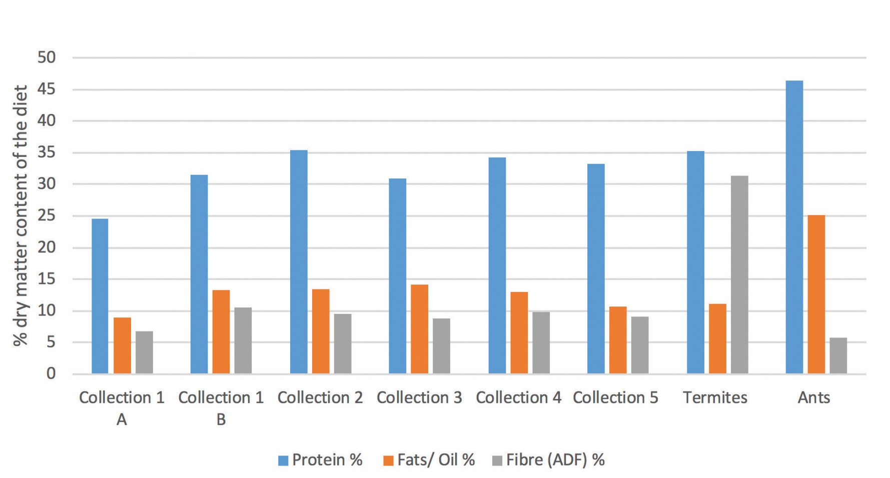

Figure 2: Analysis of the dry matter nutritional values of diets provided daily per aardvark and the nutritional composition of termites and ants from Rumpold & Schlüter (2013).

varied in the additional items offered to their aardvarks, with mealworms being the most common additional items. Only one collection did not report any invertebrates as part of their daily diet.

Figure 2 shows that none of the collections matches the nutritional composition of either termites or ants; four collections were significantly lower in protein than both termites and ants (T=-19.75, p<0.001).

Whilst Figure 2 suggests that the protein and fat values provided by the zoos did not vary largely from the values provided by the termites, the values provided by the Rumpold & Schlüter (2013) paper should be viewed with caution. This is a rough average of seven different species of termite.

Ntukuyuk *et al*. (2012) analysed the nutritional content of *Macrotermes bellicosus*, which showed nutritional variation based on the caste of the termite. Soldier termites contained around 55% protein, whereas worker termites averaged around 27%. So the composition of the diet, not just the species and amount eaten, needs to be considered.

A study by Oyarzun *et al*. (1996) reviewed the stomach contents of tamandua, taking into consideration the proportion of the different species and caste of invertebrate consumed. Comparison of the collections' diets and the results of the study can be seen in Figure 3 below. This highlights how much lower in fibre the diets are in UK collections compared to the wild diets. This could account for some of the nutritional disorders identified by Clark *et al*. (2016) including loose faeces. The protein content of most zoo diets is also lower than the 50% found in the study.

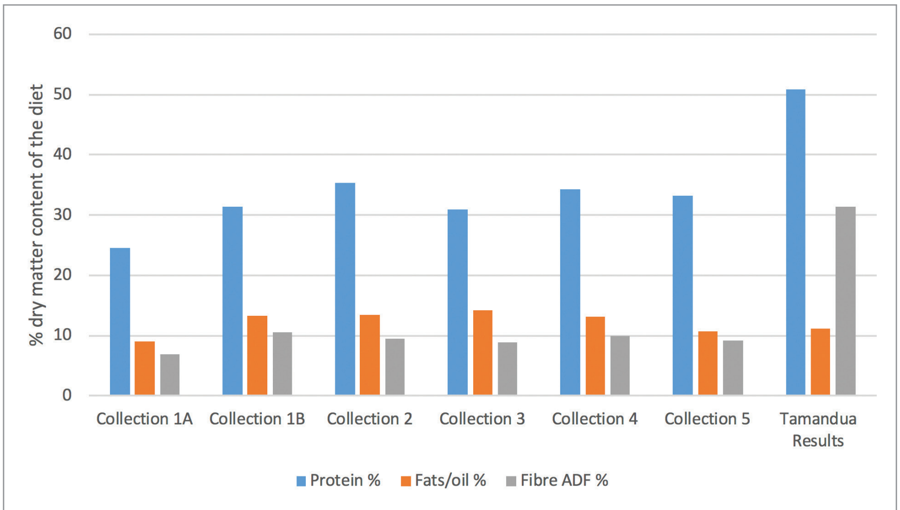

Figure 3: Comparison of the diets fed at each collection and the findings of the Oyarzun *et al.* 1996 study.

TENREC DIET ANALYSIS

Tenrecs are more generalist feeders than aardvarks, yet invertebrates make up a substantial portion of their diets in the wild (Smithsonian National Zoo, 2019). Tenrecs are increasingly found in the pet trade as well as in zoological collections, and consideration of husbandry in both industries can be beneficial in developing good practice.

An online questionnaire collated data on 23 different tenrec diets, 13 from zoological collections and 10 from private collections. Figures 4 and 5 (see right) show a comparison between the diets offered to tenrecs in zoos as opposed to in private collections. In both diets, just over one-third of the dietary items offered to the tenrecs consisted of invertebrate species. However, some of the zoo diets contained only pellets, with the Mazuri Insectivore diet being the most common pelleted diet provided.

Both groups were also asked to give their animals a body condition score (BCS) using a chart provided. Both groups reported a similar average BCS (zoo=3.2 +/-0.45, private collections= 3.2 +/- 0.62). This suggests that there is slightly more variation in the BCS of the animals in private collections. One of the tenrecs in a private collection was given a score of five, whereas none of the individuals in zoological collections scored above a four.

Because many of the diet sheets did not provide details of the exact amount of food being provided to the tenrecs, a full dietary analysis is not possible. Reviewing the dietary components suggests similar findings to Bissell (2017), with more non-structural carbohydrates being fed to less specialised insectivore species.

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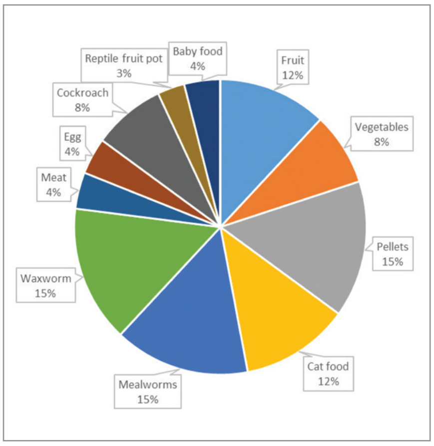

Figure 4: Dietary components provided in zoo-based diets.

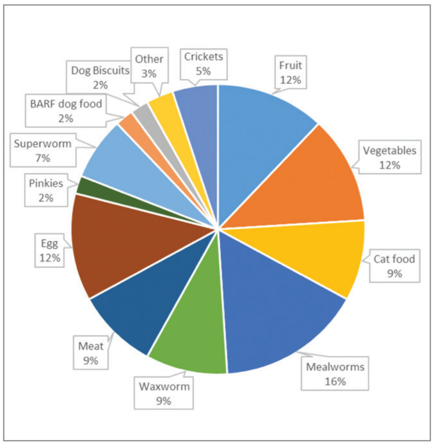

Figure 5: Dietary components provided in private collections.

The growing literature on the nutritional composition of invertebrates, as well as previous literature, suggests the need to increase fibre in diets. Consideration of chitin in dietary fibre has not been discussed here, but should be considered when reviewing fibre requirements. Current inconsistencies in both nutritional composition and components as well as the reported nutritional disorders in insectivores suggests the need for a more standardised, evidence-based approach to feeding these species with species-specific approaches. Work highlights the requirement for a more species-specific approach to diet provision in insectivorous mammal species in human care.

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STORAGE SOLUTIONS

WILLOW SILAGE – EXPLORING ALTERNATIVE TECHNIQUES

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Wintertime is a major challenge for European zoos housing browsers. An inadequate supply of browse increases the risk of health issues, such as ruminal subacute acidosis and hoof problems, but also impairs natural behaviour and thus mental health in browsers. Moreover, many other animals, such as leaf-eating primates, benefit from access to browse during winter.

ADDING ALFALFA TO DRUMS

Institutions that make browse silage mostly harvest their browse manually, which is then stored in drums with or without additives. This study compared the effectiveness of commonly used additives, with alfalfa as a new additive.

Alfalfa is currently the best alternative for browse and is known to preserve well as silage. In total, two tons of willow twigs (< 0.8 mm Ø, *Salix burjatica x S. viminalis*) were manually harvested at the beginning of June 2018. Two short-rotation willow fields, intended for biomass, were used as the willow source. The willow was pressed into 30-litre polyethylene drums with a self-developed automatic press machine to minimise the content of air.

Per additive, three drums were sampled at nine weeks and six months of storage and compared with blank drums (i.e. no additives). The nutritive value of willow did not significantly alter after ensiling, regardless of the used additive (Table 1). The addition of alfalfa, however, resulted in an end product significantly lower in fibre. However, fibre fractions – neutral detergent fibre (NDF) and acid detergent fibre (ADF) – were still much higher than pure alfalfa. Interestingly, willow ensiled in combination with alfalfa resulted in a significantly lower pH and higher content of lactic acid bacteria compared with the other additives and the blanks, which indicates a better fermentation. Moreover, the addition of alfalfa (as the only additive) succeeded in a complete disappearance of yeast and mould growth. This is an important advantage, as zoos regularly have to remove the top layer of ensiled browse in drums due to the visible growth of fungi.

Our results indicate that the addition of alfalfa improves the quality of ensiled willow in drums compared with currently used additives.

A preference test with bongos (*Tragelaphus eurycerus*) was set up

					% on dry matter basis				
Field	Willow type	Treatment*	pH	DM %	Protein	Fat	Fibre	NDF†	ADF†
1	Fresh		5.9	40.4	11.3	2.2	33.0	61.5	50.2
	Silage	Blank	5.6	31.9	13.5	1.5	30.1	68.9	54.2
		+Molasse+HFI	5.7	33.9	11.1	1.6	38.1	63.3	44.6
		Nitrogen flushing	5.7	34.9	10.2	1.6	39.3	61.3	56.1
2	Fresh		5.9	29.4	14.2	2.2	34.9	64.2	54.5
	Fresh (60%)	+Alfalfa (40%)	6.0	35.5	17.4	2.1	32.4	56.8	46.5
	Silage	Blank	5.5	29.1	12.2	1.7	37.8	68.6	55.7
	Silage (60%)	+Alfalfa (40%)	5.0	35.7	17.2	1.8	33.1	58.1	48.5

*Molasse (4% of willow (DM)) + homofermentative silage inoculant (108 CFU/kg fresh browse); nitrogen (flushing drum with 2 bar, 1.5 minutes); †NDF = neutral detergent fibre, ADF = acid detergent fibre.

Table 1: pH and chemical composition of fresh willow and willow silage after six months of ensiling.

to evaluate whether the animals preferred willow ensiled with or without the addition of 40% alfalfa. Five bongos housed at Antwerp Zoo and Planckendael Zoo were used for the trial. The two types of silage were simultaneously offered, and the researchers monitored the animals' first choice as well as the amount of willow silage consumed. There was no significant difference in preference and acceptance between willow ensiled with or without alfalfa.

WILLOW SILAGE IN BALES

Although the production of browse silage is fairly cheap and easy, it remains labour-intensive. Currently, the use of alternatives such as dried or frozen browse is not widespread due to relatively high costs or lack of storage capacity. Possibly, the commercialisation of browse silage could be a solution for many zoos. Yet to allow a lucrative commercialisation of browse silage, automatic pruning and ensiling is required.

In June 2018, a pilot study was set up to explore if willow twigs could be wrapped in round bales. The bales weighed around 500kg and were successfully stored for six months before being fed to several animal species at Bellewaerde Park.

In June 2019, a collaboration was set up with a brushwood company that owns 248 acre plantations of various Salix types. Willow (*S. viminalis* sp.) growing at the border of the plantation was automatically cut and directly wrapped in small round bales of 150kg, which are more suitable for zoo settings. The bales will be analysed after six months of storage to evaluate the quality of preservation.

FURTHER EXPLORATION

Commercialisation of the current quality of willow bales is, however, a risk for traders as the plastic can be punctured during transport. A further trial will focus on making bales from younger willow that is not yet lignified. Our research focuses on ensiling complete branches of willow to stimulate oral manipulation in browsers and to allow the animals to be selective in what they eat. However, the use of chipped willow might be more suitable to commercialise in small bales without any risk of puncturing the packaging. Therefore, in cooperation with Kiezebrink®, small bales of chipped willow will be produced and evaluated after six months of storage.

BROWSE – FRESH OR FROZEN?

THE EFFECTS OF FROZEN STORAGE ON CHEMICAL COMPOSITION, FERMENTABILITY AND PALATABILITY OF TEMPERATE BROWSE IN ZOOS

Ellen van Herk, Quality & Project Manager at New Generation Nutrition, the Netherlands; Anouk Fens, Nutritionist at Apenheul Primate Park, the Netherlands; Guido Bosch, Assistant Professor at the Animal Nutrition Group of Wageningen University, the Netherlands

Fibrous plant material, such as leaves, bark and twigs, make up an important part of the *in situ* and *ex situ* diet of browsers. Zoos often use locally available browse to support digestion and encourage natural foraging behaviour. In temperate climates, extra browse can be collected during spring and summer and stored in freezers to cover the winter months. The effects of such storage on the nutritional value and acceptance have rarely been reported. For example, ice crystal formation and enzymatic reactions might impact the nutritional value and palatability of frozen browse. We therefore evaluated whether a freezing process influences the chemical composition, fermentability and palatability of temperate browse species.

METHODS

Six of the most used browse species at Apenheul Primate Park – oak (*Quercus rubra*), willow (*Salix alba*), lime (*Tilia Americana*), maple (*Acer campestre*), elm (*Ulmus minor* and hazel (*Corylus avellana*) – were harvested in spring, in three different locations close to the zoo. Half was analysed fresh, while the other half was first stored, as branches with leaves attached, in freezers at -20°C for six months. On both time points, branches were stripped and the leaves were cut before further analysis was carried out. Leaves were chemically analysed for dry matter, crude ash, crude fat, crude fibre, neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), nitrogen, calcium and phosphorus contents. Fermentability was evaluated by incubating the browse *in vitro* with goat rumen fluid as an inoculum, and measuring gas production continuously for 70 hours and volatile fatty acid (VFA) production after 70 hours.

Besides evaluating nutritional value, feed intake behaviour was studied in two forestomach fermenting primate species (East Javan langur *Trachypithecus auratus* and Bengal Hanuman langur *Semnopithecus entellus*) and one hindgut fermenting primate species (Colombian red howler *Alouatta seniculus*). This study was done in four seasons: 1) winter: thawed browse, 2) spring: young, fresh browse, 3) summer: mature, fresh browse, and 4) autumn: both fresh and thawed browse. Using a cafeteria-style experiment, eating times and preference ranks were determined after 30 minutes event sampling on four days. On each day, the same three individuals were scored: the group's adult male, the highest-ranking adult female and a juvenile. To minimise the influence of group dynamics on feed intake behaviour, two bundles of each browse species were offered simultaneously.

	Oak		Maple		Hazel		Elm		Lime		Willow	
	Fresh	Thawed	Fresh	Thawed	Fresh	Thawed	Fresh	Thawed	Fresh	Thawed	Fresh	Thawed
Dry matter	395.2	354.2	472.9	394.8	343.5	309.1	307.5	274.2	296.7	279.2	354.4	315.4
Crude ash	34.8	34.7	54.5	55.0	67.7	66.8	97.3	97.2	86.4	91.4	92.4	89.2
Nitrogen (N)	28.0	25.7	28.1	26.9	38.1	37.5	38.5	36.2	34.6	39.1	32.7	31.1
Crude fat	27.9	30.4	24.6	30.6	15.8	26.9	26.3	28.2	37.2	38.1	26.4	25.9
Crude fibre	210.2	213.7	175.5	168.2	169.7	157.6	113.0	107.1	174.8	168.8	143.4	145.0
NDF	414.6	394.2	343.3	318.2	479.9	428.4	303.5	321.0	367.7	401.0	359.7	363.4
ADF	227.3	233.9	192.0	194.0	222.3	208.8	155.1	142.4	220.6	206.2	220.4	205.9
ADL	74.5	63.3	63.4	48.5	82.6	49.3	81.3	29.1	69.6	43.1	97.0	60.0
Calcium (Ca)	3.4	3.2	10.6	10.6	12.7	12.6	19.1	20.2	13.6	16.2	19.6	19.0
Phosphorus (P)	2.1	1.8	2.2	2.2	3.5	3.3	3.8	3.3	3.7	3.8	3.9	3.7
Gas production	244.6	186.4	227.5	200.0	202.4	161.8	336.8	275.6	333.9	276.0	296.1	232.8
Total VFAs	8.3	7.7	7.2	7.7	7.5	7.0	10.6	10.3	10.6	10.4	10.7	8.9

Table 1: Chemical composition of fresh and thawed browse species (in g/kg on dry matter basis), gas production after 70 hours of *in vitro* fermentation (in ml/g on organic matter basis) and total VFA (volatile fatty acid) content (in millimol/g on organic matter basis). NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin.

RESULTS & DISCUSSION

Results showed that, overall, fresh browse contained relatively more dry matter and ADL than thawed leaves (Table 1). The relatively lower dry matter contents in thawed leaves might be explained by water movement out of the twigs during the freezing process and collection of condensation droplets on the outside of the leaves during thawing. After thawing, this led to an overall more wet-looking product. These effects might be reduced by freezing browse in smaller packages, or using shock freezers to decrease the amount of water movement during freezing. Breakdown of lignin during storage is not likely, so changes in ADL (and other fibre fractions) might in part be explained by changes in the physical properties of the browse due to the freezing process. Such changes could have led to differences in handling (stripping and cutting) after freezing, thereby impacting the leaf to twig ratio and the amount of ADL in the analysed product.

In vitro gas production (Table 1) in fresh leaves, and thus their expected fermentability, was highest for elm and lime, while lower values were obtained for willow, oak, maple and hazel. All thawed browse showed lower gas productions than fresh browse, with decreases of 18% in elm, 17% in lime, 21% in willow, 24% in oak, 12% in maple and 20% in hazel. The production of VFAs (Table 1) was also generally lower in thawed browse compared to fresh browse. As browsers use VFAs as an energy source, lower production of VFAs from thawed browse means that browsers would have to consume more to achieve the same amount of energy. These findings could suggest that some microbial digestion of the material occurred, possibly prior to freezing. Shock freezing might prevent this effect.

In terms of palatability, both langur species and the red howlers showed less variation in eating times (Table 2) between thawed browse species than between fresh browse species. We expect that browse species that were preferred in fresh form underwent relatively more negative changes induced by freezing than the non-preferred fresh species. In that way, differences between thawed browse species could have become smaller.

In general, langurs showed preference for the more fermentable species elm and maple, while red howlers preferred the less fermentable hazel. The hypothesis here is that red howlers, as hindgut fermenters, can more easily cope with high fibre contents as all undigested fibre is passed quickly through the gut. Foregut fermenting langurs, however, are more sensitive to blockage when fibre contents in their diet are too high.

CONCLUSION

It is concluded that large differences in nutritional value and fermentability can be found between browse species. Also, each animal species shows its own preference for certain browse species. All studied animals preferred fresh browse, but thawed browse was also accepted quite well.

Feeding thawed browse is, therefore, preferred over feeding no browse during temperate winters. Even though nutritional values did not change very much after freezing, availability of nutrients might be lower in thawed browse, indicated by the generally lowered fermentability values. Provision of browse should, therefore, be adjusted per animal species, to meet their preferences, and also per season, to be able to provide browsers with the required amounts of energy and nutrients during all seasons.

		Oak		**Maple**		**Hazel**		**Elm**	
	Period	Fresh	Thawed	Fresh	Thawed	Fresh	Thawed	Fresh	Thawed
Bengal Hanuman langurs (*Semnopithecus entellus*)									
	1	-	327	-	374	-	208	-	1295
	2	64	-	227	-	105	-	937	-
	3	32	-	194	-	5	-	416	-
	4	116	43	240	192	14	8	494	474
East Javan langurs (*Trachypithecus auratus*)									
	1	-	324	-	205	-	132	-	891
	2	99	-	427	-	35	-	962	-
	3	114	-	455	-	94	-	845	-
	4	130	55	314	169	75	18	735	425
Colombian red howlers (*Alouatta seniculus*)									
	1	-	35	-	82	-	177	-	375
	2	0	-	243	-	239	-	624	-
	3	2	-	249	-	210	-	513	-
	4	0	7	215	27	212	93	525	199

Table 2: Number of seconds spent eating each browse species by one animal, during 30 minutes scoring, averaged over three individuals and four days per period. - = not offered in this period.

FEEDING HABITS

CONSIDERING THE BEHAVIOURAL CONSEQUENCES OF FEEDING REGIMES – A FLAMINGO CASE STUDY

Paul Rose, University of Exeter, UK, Research Associate, Wildfowl & Wetlands Trust

Zoos hold large numbers of dietary specialists who consume specific food with peculiar anatomical and morphological features. Flamingos (*Phoenicopteriformes*), for example, are extreme dietary specialists (del Hoyo, 1992) but very common zoo birds (King & Bračko, 2014). Time spent on non-feeding behaviours can also be directly influenced by nutrition and feed presentation. Chemical compounds within food are metabolised to produce colours that are used for sexual selection and provide a signal of individual quality. In some species, the onset of the breeding season will change the time spent on specific maintenance behaviours to provide a stronger reproductive message. Greater flamingos (*Phoenicopterus roseus*) that are more efficient foragers will spend more time preening at the start of the breeding season, wiping carotenoid-stained preen oil over their feathers and thus cosmetically enhancing the brightness of their plumage (Amat *et al*., 2011). A heightened pink colouration increases chances of pairing and producing a chick.

Flamingos kept in human care must be artificially supplemented with carotenoids, provided in a complete pellet, otherwise they gradually fade to white. Flamingo pellet is a limited resource and highly sought after by the birds. Increases in aggression around feeding times and in feeding areas can be detrimental to time spent foraging, and this may impact on the attainment of pink colouration. Juvenile flamingos can be subjected to more aggression than adults within foraging patches, and as they have increased energetic demand compared to adults, such aggression could negatively impact upon growth and development. Aggressive interactions between feeding wild flamingos are noted (Bildstein *et al*., 1991; Schmitz & Baldassarre, 1992) and can significantly decrease the time birds spend filter feeding (Bildstein *et al*., 1991). Wild flamingos have more space to distance themselves from other foraging birds; restricting access around high-value resources (e.g. pellets) can artificially increase stocking density and therefore increase aggression during feeding (Bildstein *et al*., 1993; Rose, 2019; Rose *et al*., 2014). Wild flamingos attempt to maintain equal distances between themselves and others during foraging (Schmitz & Baldassarre, 1992) therefore in-zoo feeding must consider the behavioural choices of the birds to maximise intake and reduce food wastage.

Figure 1: Different feeding styles for captive lesser flamingos (top left) as well as the extent of pink colouration of each individual bird's feathers (top right) may influence the degree of aggression experienced by foraging birds (bottom).

CASE STUDY

To determine the impact of husbandry and phenotype (colour) on population and individual foraging, 46 lesser flamingos (*Phoeniconaias minor*) at WWT Slimbridge Wetland Centre in the UK were observed whilst feeding in four different situations: pellet provided in a bowl/trough, indoor feeding pool, outdoor feeding area and natural foraging (i.e. filter feeding on aquatic material in their pool). Counts of seconds each bird spent feeding/foraging and being aggressive were recorded. The same data were then recorded for the group overall. The number of feeding birds, their individual identifier (from plastic leg rings), age and sex were noted. Colour scoring was based on the degree of white to pink feathers on the bird's body, going from all white to mainly white, mainly pink and all pink. Figure 1 shows these different feeding situations, bird colour differences, and the specific behaviours observed.

Results showed that paler flamingos spent more time foraging than those of a more intense plumage colour. Foraging was influenced by the foraging location as well as by the number of birds foraging. There was no influence of colour on aggressive differences between birds. Aggression increased, and foraging therefore decreased, with flock size. At an individual level, male flamingos were more aggressive during foraging bouts than females. Flamingos spent the least time foraging when they were feeding from bowls, compared to when they were naturally filter-feeding in their pools.

Flamingo foraging is clearly influenced by the mix of birds in the group and the location and placement of flamingo pellet. Colour may be of relevance to foraging effort, with birds of a paler colour attempting to gather more energy and more carotenoid to improve plumage condition at the next moult. Given the multi-factorial reasons for flamingo feeding style and colouration, it is likely that colour signals between birds will dictate differences in time spent feeding based on physiological demand and individual energy requirements, which change with season (i.e. in and out of courtship and breeding events). Time sent preening versus feeding and plumage colour score would make an interesting research extension.

Flamingo plumage colour will change markedly after breeding (Figure 2), and while these lesser flamingos did not produce chicks during the observation period, birds did moult into brighter colours for courtship display and became paler towards the end of summer. As the social dynamic of a flock, specifically mate choice, is influenced by colour, flamingos that cannot gather food effectively may be unable to metabolise enough carotenoid into growing feathers to produce a bright enough signal to interest others in breeding. This may have profound and long-lasting efforts on population sustainability. Differences between the plumage colour of captive (paler, uniform) and wild (brighter, variable) Andean (*Phoenicoparrus andinus*) and James's flamingos (*P. jamesi*) are one of the reasons why these species have fared poorly in the zoo (Kear & Palmes, 1980).

CONCLUSION

The dietary requirements of flamingos and their specific means of collecting food strongly influence their daily time-activity budgets. Zoos need to consider colour for all important aspects of the flamingo's life in the zoo – from how they attain their pink, red, orange and purple colours to how they would prefer to forage, based on evidence in the literature on wild birds. Flamingos should be fed in a manner that promotes group foraging, in enclosure areas that allows sufficient space between birds to reduce aggression, which impacts on individual and group feeding effort.

Figure 2: Colour differences in captive Andean flamingos following a breeding event. Birds that produced crop milk are much paler than those who were not reproductively active.

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A PLACE IN THE SUN

A STUDY OF PRIMATES' NEED FOR VITAMIN D SUGGESTS THAT MORE WORK IS NEEDED ON THIS VITAL TOPIC

Geert Janssens, Ghent University, Belgium

Vitamin D has been in the spotlight for several years now, because many scientific studies have pointed to the low vitamin D status in the human population. One of the main causes is the lack of exposure to UVB light from the sun, suggesting that we should all spend more time outside. Vitamin D supplements are now widely available and recommended as a solution to a wide array of health issues. Most people know that vitamin D helps to maintain a healthy set of bones, but there is now solid proof that it has a much wider impact than just calcium metabolism. Its impact ranges from increasing immune competence to solving particular types of mental depression.

Several northern European zoos anecdotally reported issues with their primates, which appear depressed, particularly in winter. When routine veterinary checks were done, the blood level of vitamin D (measured as 25-hydroxy-cholecalciferol 25OHD3) often seemed lower than clinically healthy levels in humans.

There are no solid reference values for many primate species, but because of the above findings, it was considered worthwhile to look into vitamin D status in primates in zoos. In a cooperation between Christine Kaandorp, Andrea Brenes Soto and Geert Janssens, their master student Romy van Noije collected existing data on 25OHD3 serum concentrations from various primates in Dutch and German zoos, with a majority of chimpanzee samples. To compare with counterparts in a more natural habitat, 25OHD3 data were also collected from sanctuaries with chimpanzees in Angola, Sudan, Guinea-Bissau and Rwanda.

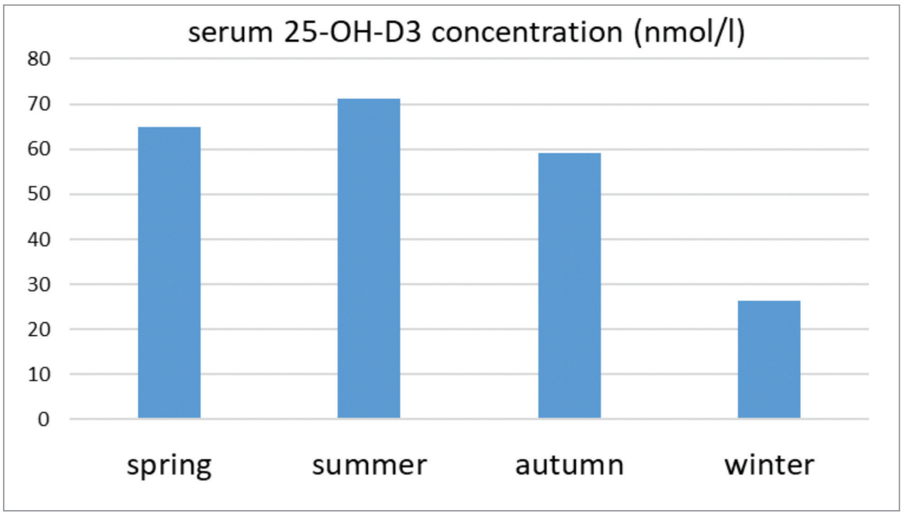

Figure 1: 25OHD3 changes during the season.

After statistically analysing the data sets, it was seen that the vitamin D status in the zoos was lower when primate species had a darker skin colour. This is a logical finding, confirming that the dark pigment is protecting primates in natural habitats with high UV exposure. Evidently, in northern European zoos, natural UVB is much lower than in many natural primate habitats, and can become close to zero in winter season. The study indeed showed that vitamin D status decreased from summer to winter across all species. Because this was an associative study, we must be careful to draw hard conclusions, because some factors may have been intermingled: for instance, New World and Old World primates are provided differently with dietary vitamin D3, since it is well known that New World primates have a higher dietary requirement for this vitamin. Despite these confounders, the results are still striking, and point to a potential nutritional concern for primates kept in regions with lower UVB exposure than in their natural habitat.

Many zoos are aware and do provide vitamin D supplements, but from the analysed data set, no clear effect of using supplements was found. Maybe that means that a more detailed and targeted study is needed, but it could also indicate that UVB exposure, such as through UV lights, may be a more helpful way in which to increase the vitamin D status compared to dietary supplements only.

More insight was gained when focusing on the available data from chimpanzees in the zoos versus those in the African sanctuaries: the 250HD3 levels of chimpanzees in the African sanctuaries were twice as high (about 120 nmol/liter) as those in the zoos. This does support the idea that UVB from sunlight in the natural habitat guarantees a better vitamin D status in those animals. It was notable also that in the African situation a seasonality was observed, which can be explained by the difference between dry season and rainy season. Some seasonal variation thus can be considered natural, but the absolute serum concentrations of 25OHD3 were considerably lower in the zoos than in the natural habitats.

What this study could not identify is whether this lower vitamin D status of primates in zoos is the actual cause of certain health issues. It nevertheless warrants further efforts to find out how the vitamin D status is best increased in those animals (through diet, supplements, UVB lamps, housing or combinations), and if that can trigger a positive impact on their physical and mental health.

BACK ON THE MENU

AN ANIMAL NUTRITION MEETING AT EAZA'S ANNUAL CONFERENCE COVERED A RANGE OF VITAL TOPICS FROM BROWSE STORAGE TO CARNIVORE FEEDING TECHNIQUES

Anouk Fens, Nutritionist, Apenheul Primate Park, the Netherlands, and Chair EAZA Nutrition Group

One of the best ways in which we can pursue our aim 'to promote and support nutrition in zoological institutions as an essential component of their conservation mission' is to discuss the vital topic of zoo animal nutrition at the EAZA Annual Conference. After some years of absence, we were happy to have the topic back on the programme again. At the 2019 EAZA Annual Conference in Valencia, the EAZA Nutrition Group hosted a well-attended meeting, representing a selection of relevant talks that had been presented at the EAZA Nutrition Conference in Marwell in January. After a word of welcome from Anouk Fens (Chair EAZA Nutrition Group), Francis Cabana (Wildlife Reserves Singapore) kicked off with his talk on geriatric zoo animal nutrition. Old animals are becoming more and more common in zoos and this is a testament to the increasing levels of good health and welfare that we can provide. As animals live longer and longer we begin to see some health issues related to old age, very similar to health issues that we feel ourselves as we age. Very little information exists on how to support geriatric wild animals, but in a series of trials, Wildlife Reserves Singapore provided taxa-specific geriatric diets. Within four months, they found that these diets helped to alleviate symptoms of arthritis as well as increasing activity levels.

Next to speak was Christian Schiffmann (University of Zurich), who presented the results of his PhD study on body condition scoring (BCS) in European zoo elephants. In order to monitor physical condition and health in zoo animals, visual BCS is a helpful tool. Several species-specific protocols have been validated for elephants. Although a trend towards the ideal scoring range has been detected in European zoo elephants during the past years, excess weight and obesity still represent a population-wide challenge. Hence, further diet and management adaptations as well as a documentation of the scores are strongly recommended by Christian. To facilitate documentation for elephant-holding facilities, a BCS online archive has been established. This tool allows individual access for each zoo to the data collected for the elephants under their care and monitoring of their BCS development.

LECTURER AND RESEARCHER SARAH DEPAUW PRESENTS HER FINDINGS ON SILAGE ADDITIVES

Sarah Depauw (Odisee University College) was next to take the floor, presenting the first results of her study on willow silage techniques (see pp. 14-15). Browse silage can be used as winter feed for leaf-eating animals and is often manually harvested and stored in drums. Sarah's study compared the effectiveness of commonly used additives, such as nitrogen, molasses and lactic acid bacteria, with alfalfa as a new additive. The nutrient content of the browse remained largely unaltered during six months' storage, and the animals did not show any preference among the additives. Interestingly, the addition of 40% alfalfa was the only additive that resulted in a complete disappearance of yeast and mould. This is an important advantage since zoos regularly have to remove the top layer of ensiled browse in drums due to the visible growth of fungi. Although the production of browse silage is fairly cheap and easy, it remains labour-intensive. Therefore, current research is exploring the commercialisation of willow silage, which is automatically cut and wrapped in round bales of 150kg.

The final talk was given by Marcus Clauss (Zurich University). Marcus spoke about basic aspects of carnivore feeding related to behaviour: the value of feeding whole prey as opposed to processed material, the relevance of feeding frequency (which may differ enormously between species, with some carnivores not feeding on a daily basis, yet others naturally feeding up to 10 times per day), different ways to make the animals work for food (including pole-feeding, swinging platforms, lure lines, counterweights), and finally a vision of developing feeding systems that include the option of failure. He emphasised that only if you provide the opportunity of failure do you really provide the opportunity for achievement. To date, no feeding systems appear to exist that require complete dedication on the part of the predator – because in the end, the animal will always receive the food. If there was a chance to go hungry (for an appropriate, species-specific period of time), the lives of carnivores in human care could gain meaning in an unprecedented way.

We would like to thank all the speakers who contributed to this extremely useful session, and all the delegates who attended and showed an interest in animal nutrition.

DESIGNER DIET

THE EFFECTS OF DIETARY ALTERATIONS ON BEHAVIOUR AND DAILY FOOD INTAKE OF GIRAFFES AT PAIGNTON ZOO ENVIRONMENTAL PARK

Louise Cox, Nutrition Assistant, Wild Planet Trust, UK; Daniel Harrold, Scientific Assistant – Nutrition, Chester Zoo, UK; and Amy Plowman, Director of Living Collections, Wild Planet Trust

Giraffes are a particularly challenging species to feed appropriately. Due to their morphology as browsing ruminants, constant access to forage is necessary. Many zoos face challenges providing adequate amounts of browse for giraffes due to the large quantity they require, and they can be particularly picky with lucerne consumption. It has been reported that some giraffes in human care have died from inadequate diets that have not provided enough energy. Additionally, oral stereotypies are not uncommon in giraffes that are kept *ex situ*, and it is thought that this may be related to feeding routines (Fernandez *et al*., 2008).

GIRAFFES AT PAIGNTON

At the time of study, Paignton housed 1.6 giraffes, ranging from one to 13 years old with the male kept separately from the females overnight. Stereotypic behaviours had been reported by keepers, including potential anticipatory pacing before feeding time. A low body condition score (BCS) was reported in an adult female, and one juvenile female had a high BCS.

Initially the aims of the pilot study conducted in April 2018 were to monitor food intake for individual giraffes and quantify the prevalence of stereotypic behaviours. The diet

		Pilot study – females		Pilot study - male		Outside/All
Food item	Diet sheet (for whole group)	Average offered	Average consumed	Average offered	Average consumed	
Pellet	23	18.81	18.70	3.3	3.23	N/A
Lucerne (overnight)	*Ad libitum*	31.89	31.14 (97.7%)	14.05	(82.6%)	N/A
Dengie Hifi	*Ad libitum*	2.57	2.57 (100%)	1.06	1.06 (100%)	N/A
Cabbage	14	14.08	13.58	2.43	2.36	N/A
Browse	As much as possible	N/A	N/A	N/A	N/A	11.73 offered (62.37% consumed)
Lucerne (daytime)	*Ad libitum*	N/A	N/A	N/A	N/A	26 offered (79.2% consumed)

Table 1: Diet composition for the giraffe herd and diet being offered and consumed during the pilot study in kg.

	Condition 1	Condition 2	Condition 3	Condition 4
Change made	Increase Hifi and lucerne provision	Increase browse provision	Pellet change	Randomising time of afternoon feed + additional browse overnight
Time frame	Permanent change	June 2018	July 2018	August 2018

Table 2: The four conditions following the pilot study.

(see Table 1 for composition) was supplied in two feeds a day. At 08:00 and 16:00, pellet and cabbage was fed in the inside enclosure, and intake recorded as a group for the females and individually for the male. Lucerne and browse were fed outside from approximately 09:00, and monitored over the day for the herd as a whole (browse was weighed before and after going in the enclosure, and the amount of lucerne was estimated by the number of sections offered and remaining). Lucerne was also fed inside overnight and cameras were set up to monitor consumption over time.

The giraffes had access to the outside paddock between approximately 09:00 and 16:00, providing the weather was suitable (warm and dry). Behavioural observations were conducted throughout.

PILOT STUDY

The pilot study highlighted significant diet drift compared to the diet sheet. For the females, 428g of Dengie Hifi (a straw, alfalfa and molasses mix) was provided per individual on average with 100% consumed, therefore not being provided *ad lib*. Lucerne provided overnight varied dramatically for the male with a range of 6.69kg to 22.3kg offered. Similar variation was seen with the females with 10.43kg to 47.87kg offered. In five out of nine days there was no lucerne left in the mornings. Additionally, the amount of browse offered daily had a large variation (7.23kg to 16.8kg) and was generally not considered to be enough.

Based on these findings, we created four conditions (Table 2). The pellet was changed from Dodson & Horrell Ruminant Browser Cubes (made by Dodson & Horrell Ltd) to Boskos Browser pellet (a high-fibre acacia-based pellet sold by Kiezebrink International BV). Quantity of the pellet ration changed slightly to account for differences in energy density.

The final condition involved randomising the time of the afternoon feed between 15:30 and 16:30. Behavioural monitoring continued and anticipatory behaviour was recorded for the hour before access into the inside house in the afternoon.

INTAKE RESULTS

During condition 1, female Hifi intake increased from 427g per individual to 1023g. The male Hifi intake increased from 1060g to 1897g and 85.9% consumption. Lucerne offered overnight for the females increased, but there was still a huge variation in what was offered – from 12.5kg to 44.8kg (92.5% consumed). Lucerne offered to the male also ranged from 8.80kg to 30.5kg with an average of 19.24kg (64.5% eaten). During the increased browse condition, 23.04kg of browse was offered on average, more than double the 11.73kg provided in the pilot study.

Camera trap images showed larger quantities of lucerne last longer into the night, as expected, and 44kg of lucerne provided overnight in the final condition had lucerne remaining on 80% of mornings. During the other three conditions, feeders were emptied by 22:15 at the latest, with the earliest average time being 20:44 in condition 1, despite having the second highest amount of lucerne provided on average, at 32.06kg. It is essential that sufficient quantities are provided to ensure access to food is available at all times. Photographs also seemed to indicate the presence of stereotypic behaviours at night, and further research into the behaviour of these animals during the night would be beneficial.

Overall, there appeared to be little change in the giraffes' behaviour between the conditions. Anticipation was monitored by pacing rates, which increased over time towards feeding time. In condition 4, the unpredictable feeding times, there appeared to be more time spent being inactive, and thus not pacing.

TAKE-HOME MESSAGE

The main finding of this study was the large variation with the diet offered and the presence of dietary drift. The designed diet was deemed appropriate; however, there was large variation in what was being provided.

Diet-related terminology should be explained clearly, as for example, *ad libitum* was not being provided *ad libitum*, potentially due to confusion around what *ad libitum* means.

Furthermore, a minimum amount for ‘as much browse as possible’ should be quantified to ensure enough is being provided. It is vital that consistent and constant monitoring of diets is completed, to ensure an accurate understanding of the diet being consumed. Overall, no obvious differences in the general behaviour or intake of the giraffes was seen between the different husbandry changes.

Since this study was undertaken, further husbandry changes have been implemented and browse is being provided overnight as well as during the day. Further research into behaviour of the herd at night would also be beneficial.

CHEWING IT OVER

NATURALLY OCCURRING BODY WEIGHT FLUCTUATION IN ADULT ELEPHANTS

Christian Schiffmann, Marcus Clauss and Jean-Michel Hatt, Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Switzerland; Stefan Hoby, Basel Zoo and Tierpark Bern, Switzerland

It is well known that zoo elephants often have a higher bodyweight, and a body condition score (BCS) pointing towards obesity, when compared to free-ranging conspecifics (see Figure 1). In addition, negative consequences for reproduction have been suspected, with a putatively lower reproductive output in heavier, or obese, animals.

We set out to test this relationship in the European zoo elephant population and collected as many bodyweights as possible. And indeed, the available data showed that non-breeding females were generally heavier than breeding females of a similar age. Of course, our survey cannot prove a causal relationship, and one cannot be sure whether it is the bodyweight that influences the breeding, or the breeding that influences the bodyweight. However, non-breeders seem to be heavier as juveniles, when their breeding activity cannot yet influence how heavy they are (Figure 2). Therefore, we think it is prudent to aim at moderate body-weights, and a normal, non-obese body condition in zoo elephants.

The use of BCS (reviewed in 2018; Schiffmann, Clauss, Hoby & Hatt, 2017), as well as an individual-specific archive of body condition over the elephants' lifetime and regular weighing if scales are available can help to achieve that aim. It is important to consider this to be a constant monitoring process, rather than something that is decided or achieved once and then considered done.

When inspecting the data that we collected, we realised that mature elephants do not appear to have a constant adult bodyweight, but that there are fluctuations in bodyweight (for both breeders and non-breeders) that occur over as much as 100 months (Figure 2). This pattern was also observed in African elephants, and it matches some anecdotal reports found in the literature (Schiffmann *et al*., 2019). What could be its cause?

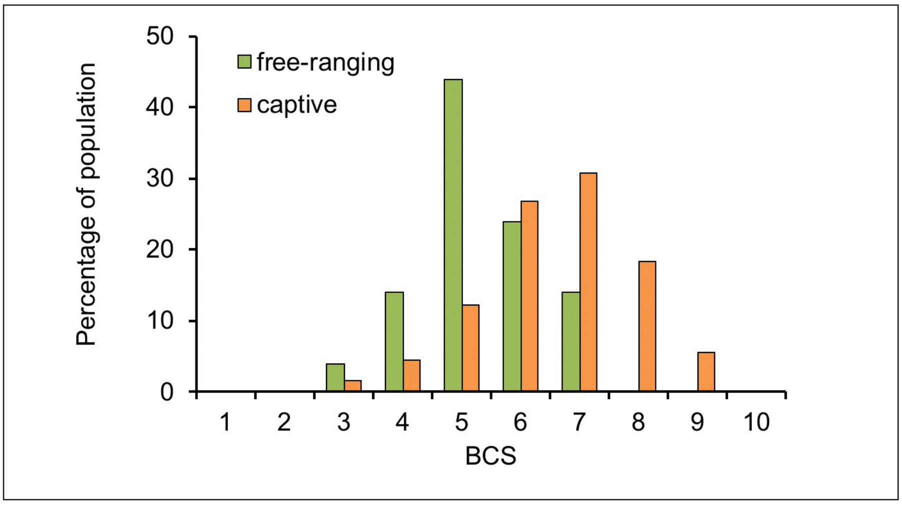

Figure 1: Comparison of the body condition score (range 1–10) of adult female Asian elephants (*Elephas maximus*) in a free-ranging population and the European zoo population (from Schiffmann *et al*., 2018).

In our opinion, the only convincing explanation lies in the peculiar dental anatomy of elephants. Let us explain first the normal tooth eruption process in elephants, that has been called a 'rolling carpet' or 'molar progression'.

Elephants do not change their teeth once, as most mammals, but five times during their lives. They have six cheek teeth per jaw-side, but there is generally only one erupted and functioning, while the next one is being built inside the jaw behind it (Figure 3). The new tooth will slowly push forward, and the old tooth will fall out, not all at once as a whole, but gradually breaking off, fraction by fraction. If not swallowed by the elephant, keepers may find these pieces of broken-off tooth in the enclosure. This mechanism is considered an adaptation to the enormous body growth from juvenile to adult in elephants – if an elephant would change teeth once like we do, from milk (deciduous) teeth to permanent teeth, yet its jaw would keep growing, there would be increasing spaces between the teeth. With its 'progressive' dentition, the constantly increasing tooth size from the first to the sixth cheek tooth keeps adjusting tooth size to jaw size throughout the elephant's lifetime.

Most likely, this leads to a peculiar effect that sets elephants apart from most mammals. Usually, in mammals, the functional chewing surface first becomes more until all teeth are fully erupted, and then becomes less again in old animals as teeth are worn or even fall out. In elephants, there is a constant change between the situation where a single tooth is present in the jaw, and the situation where the new tooth has already broken out quite far, but the old has not completely

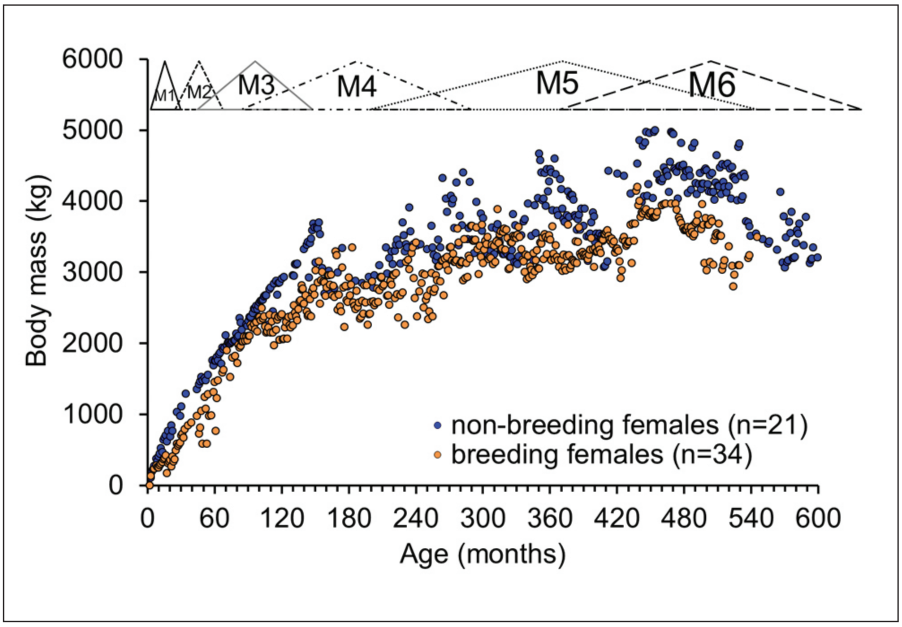

Figure 2: Bodyweights in female Asian elephants (*Elephas maximus*) kept in European zoos in relation to their age. Data represent averages for the respective ages of all animals for which bodyweight data were available. Note the difference between breeding and non-breeding females that appears evident already at an early age. Also note the fluctuation in the adult animals (from Schiffmann, Hatt, Hoby, Codron, & Clauss, 2019). The average presence of cheek (molar = M) teeth 1–6 is indicated by triangles on top of the graph.

fallen out yet. In the latter situation, the chewing surface may be larger than in the former situation of a single tooth present, and thus the size of the chewing surface will fluctuate repeatedly throughout the elephant's life.

We believe that this is the best explanation for the observed bodyweight fluctuations; when the chewing surface is larger, elephants can either eat more with the same chewing efficiency, or eat the same amount with a higher chewing efficiency – either way, it will have more digestible energy at its disposal.

In the wild, variation in the natural vegetation and in the amount eaten between the dry and wet seasons will most likely overrule this signal. In zoos, with a more consistent diet, this signal might just be detectable. When monitoring the body condition and the bodyweight of an individual animal, its dental status is one possible reason for a change in weight. If one wanted to test whether our hypothesis is right, one would have to track bodyweight in several individual animals over time and constantly monitor their tooth status – over decades.

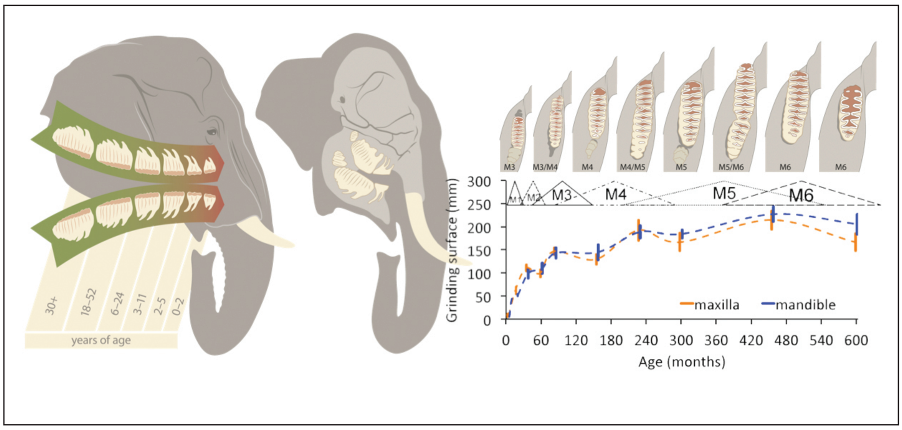

Figure 3: Visualisation of the sequence of tooth replacement in elephants with age, indicating the progression of the six molars in an African elephant, the placement of teeth at a certain moment of the progression sequence in the jaw bones in an Asian elephant, the variation in the length of the molar 'grinding surface' at estimated age points and the extrapolated undulating time course in Asian elephants based on literature data (Roth & Shoshani, 1988) compared to molar replacement periods (modified from Johnson & Buss, 1965) according to literature, with pictograms of the mandibular molar surface of African elephants adapted from published drawings (Laws, 1966). The average presence of cheek (molar = M) teeth 1–6 is indicated by triangles on top of the graph. Pictograms not to scale. ©2018 Vetcom – Pascal Glatzfelder. Figure taken from Schiffmann *et al.* (2019).

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CREATING A BALANCED DIET

CONCENTRATE- AND PRODUCE-FREE DIETS FOR ZOO RUMINANTS – IS IT POSSIBLE?

Marcin Przybyło and Paweł Górka, University of Agriculture in Krakow, Poland; Alina Kloska, Silesian Zoo, Poland; Łukasz Różański, Warsaw Zoo, Poland; and Karolina Kasprzak, Wroclaw Zoo, Poland

In spite of the recommendation that herbivores should not receive grain-based concentrates and fruit, typical diets for ruminants in zoos often contain substantial quantities of exactly those things: fruit, vegetables and different forms of cereal grain, in addition to roughage and browse. Taking into account that ruminants evolved to consume difficult-to-digest foods that are often very high in fibre, the inclusion of concentrates or fruit in their diet seems to be especially unjustified. So is it possible to stop feeding these foods to zoo ruminants?

WHY CONCENTRATES AND PRODUCE IN THE DIET?

Diets for ruminants in human care should promote the intake of structured feeds (roughage and browse) and limit the intake of unstructured feeds, especially those highly fermentable in the rumen (cereal-based products, fruits and vegetables). This strategy is necessary to stimulate normal eating behaviour and rumination and to prevent disturbing the gastrointestinal tract function. Structured feeds resemble food consumed by ruminants in the natural environment. Their intake results in a slow fermentation rate in the rumen and stimulates rumination and saliva production, and thus ensures that pH in the rumen is within a range optimal for its function. Intake of structured feeds also prevents the abnormal, stereotypic behaviours often observed in zoo ruminants. However, it has been shown that some roughages offered in zoos, i.e. grass or meadow hay, are not willingly consumed by some ruminants, particularly browsers. This leads to an insufficient intake of nutrients which does not meet the animals' requirement. In consequence, in order to prevent weight loss and other related health problems, unstructured feeds are often fed to zoo ruminants. In many cases these are cereal-based pellets that are high in starch (and energy). Altogether, a low intake of structured feeds and the presence of unstructured feeds in the diet leads to a high proportion of the latter in consumed dry matter.

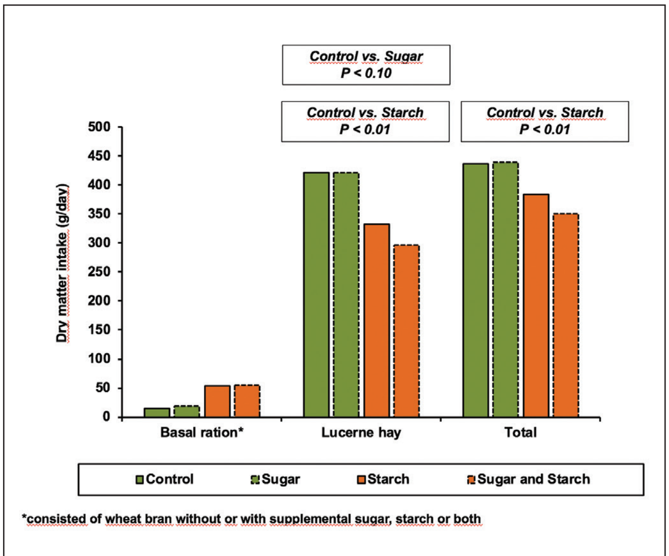

Figure 1: Effect on feed intake by muntjac of supplementation of sugar, starch or both in the diet.

IS HIGH INTAKE OF CEREALS OR FRUITS A PROBLEM?

The current rule of thumb for zoo ruminants is that unstructured feeds should not exceed 50% of ingested dry matter. Based on our experiences, this recommendation could be halved, even when it comes to feeding quite demanding species of ruminants. Unfortunately, the recommendation is often not met, but instead exceeded.

Is it a common problem to overfeed zoo ruminants with cereal-based concentrates or produce? Maybe not in most modern zoos, but one cannot be sure without strict control of diet composition and precise measures of feed intake. Feeding recommendations are proposed by scientists or zoo nutritionists, then applied and finally 'verified' by the animals. However, 'dietary drift' is possible at each step of the process. The greater the 'dietary drift', the greater the chance that animals will not eat what they are supposed to eat.

Our studies showed that unstructured feeds may account for up to 80% of dry matter ingested by zoo-kept ruminants, although the diet looked fine on paper. What we observe is that in most cases this is a result of poor-quality roughage offered to ruminants or feeding non-preferred roughages, i.e. grass hay to typical browsing ruminants. Even if the amount of concentrates and produce is set at a low, 'safe level', a low intake of roughage may lead to energy deficiencies and poor body condition. As a result, the amount of unstructured feeds is often intentionally increased in order to maintain adequate energy intake and desired body condition. This, however, may further reduce the intake of roughage, and thus further increase the problem of low feed intake and poor body condition, as well as a high probability of diseases related to the gastrointestinal tract.

SUGARS VS. STARCH

Non-fibre carbohydrates, particularly sugars and starch, are known to have a negative impact on the gastrointestinal tract of ruminants when consumed in too high amounts. Both are rapidly fermented in the rumen and thus their increased intake may lead to subacute or acute rumen acidosis, low feed intake, diarrhoea and hoof problems. Sugar content (i.e. mono-saccharides and disaccharides)

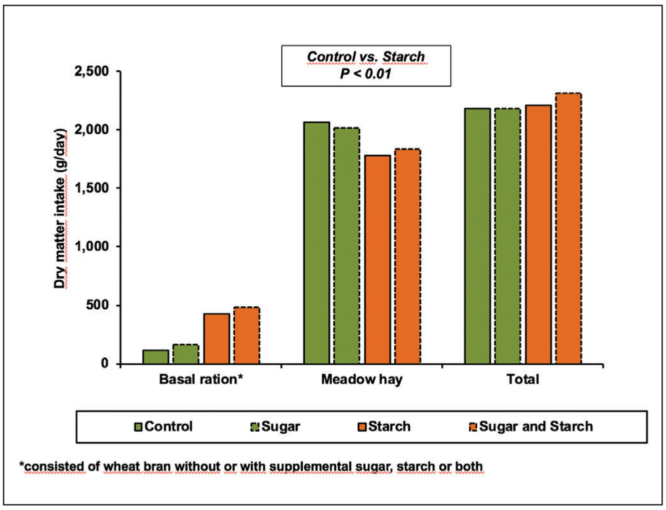

Figure 2: Effect on feed intake by addax of supplementation of sugar, starch or both in the diet.

in both natural browse and grasses can vary greatly (from 5% to 20% of dry matter), which may lead to a substantial intake of sugar by ruminants even on diets based mostly on roughage. The impact of sugar ingested with roughage on an animal's overall feed intake and health has not been investigated in zoo ruminants, but may suggest that many species of zoo-kept ruminants may be quite well adapted to the contents present in natural forages.

On the other hand, starch intake by ruminants in the natural diet is rather negligible. Therefore, intake of starchy foods by zoo ruminants should be considered as especially undesirable. However, high-starch cereals are often the main component of pellets for zoo ruminants, due to their low price, high energy content and good binding characteristics. Numerous studies show a negative impact on the functioning of the rumen and lower parts of the gastrointestinal tract of ruminants where there is a high intake of starch. In our opinion, intake of starch is more problematic than intake of sugars and is responsible for most of the health issues related to the nutrition of ruminants in human care.

In order to test whether an increased intake of starch with cereal-based foods is more problematic for ruminants in human care than an intake of sugars with fruits, we have conducted two studies. The first was on Reeves's muntjac (*Muntiacus reevesi*) and the second on addax (*Addax nasomaculatus*), representatives of browser and grazer ruminants respectively. In both studies, animals were fed a diet without concentrates and produce, or a diet that was supplemented with wheat (a source of starch), sucrose (a source of sugar), or both. Wheat and sucrose were supplemented in amounts ensuring an intake of starch (15% of dry matter) and sugar (2% of dry matter) with concentrates and produce that was similar to that observed in zoo ruminants fed a typical diet for this group of animals, at least in some zoos in Poland. It has to be mentioned that these amounts do not represent possible extremes (based on reports available in literature) and should instead be considered as moderate. Note that the impact of feeding sucrose may not necessarily be the same as the impact of feeding fruits, but our experimental model allowed us more precise control over the animals' sugar intake.

Sugar supplementation had a minor or no impact on the intake of roughage by muntjacs (Figure 1) and addax (Figure 2). On the other hand, starch supplementation decreased intake of lucerne hay by muntjac and meadow hay by addax. In muntjacs, starch supplementation had a much more negative impact on the intake of roughage than that observed in addax, and resulted in a substantial reduction in the total intake of dry matter. Taking into account that in our experimental model inclusion of wheat in the diet was rather moderate, a much more negative impact on roughage intake can be expected when concentrates account for more than 15-20% of ingested dry matter – which does not seem to be uncommon in zoos, according to available reports. The same applies for overfeeding of produce, which may account in some cases for more than 5% of ingested dry matter by zoo ruminants. A high or very high intake of produce may also lead to negative or very negative consequences.

Based on the results of these two studies it can be concluded that:

1) feeding starchy feeds (concentrates) to zoo ruminants has a greater negative impact on roughage intake than feeding sugary feeds (fruits); and
2) this impact is probably much more apparent in browsing than grazing ruminants.

However, the results of our studies may also be interpreted in another way. Animals on control diets (only on good quality roughage) were maintained without any negative consequences, e.g. no negative impact on body condition or bodyweight. In line with the results of our rather short-term studies, Tahas *et al.* (2017) found no negative impact as a result of feeding addax-only grass hay for three months. Taking into account some differences in the anatomy and physiology of different groups of ruminants, the impact of starchy and sugary feeds in the diet may affect browsers and grazers differently.

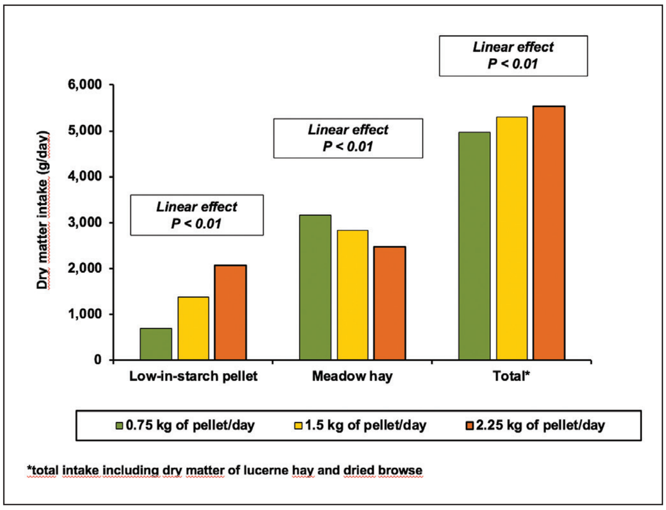

Figure 3: Effect on feed intake by bongo of low-starch pellet in the diet.

Browsers are probably much more susceptible to improper nutrition than grazers, and increased intake of produce and concentrates may decrease the roughage intake much more in browsers than grazers, as shown in our study on muntjacs. In consequence, long-term overfeeding of concentrates or fruits may have especially negative consequences for browsers.

LOW-STARCH PELLETS INSTEAD OF CONCENTRATES

Cereals or cereal-based pellets, which seem to be the most problematic components of the diets for zoo ruminants, could be replaced with low-starch pellets. Such pellets would not have a negative impact on gastrointestinal function, but would still allow for the presence of 'concentrates' in the diet. Low-starch pellets could be based mainly on milled roughage and other high-fibre foods (dehydrated grass or lucerne, dry tree leaves, bark, etc.), which ensures a negligible amount of starch in formulated feeds. Presently, some commercial companies produce such products for zoo ruminants.

In order to test whether low-starch pellets could be a valuable feed for zoo ruminants, we conducted a study in which bongo antelopes (*Tragelaphus eurycerus*) were fed diets with increasing amounts (0.75kg, 1.5kg or 2.25kg/day) of such pellets – 14% crude protein, 50% neutral detergent fibre (NDF) and 29% acid detergent fibre (ADF). With the exception of a few cases when the highest amount of pellets was fed to some animals, pellets were always completely eaten. Dry matter intake increased with increasing amounts of low-starch pellets offered in the diet, but the intake of meadow hay decreased. Our study was a dose-dependent study, and the greater the intake of pellet, the lower the intake of hay (Figure 3). Furthermore, with the highest amount of low-starch pellets in the diet, a faster eating rate (g of dry matter/min) and shorter rumination time (min and min/g of dry matter) was observed. Irrespective of a final recommendation on the optimal daily dosage of low-starch pellets for bongo, in this study the animals were maintained almost without starch foods (only a small inclusion of oats), fruits or vegetables. The total dry matter intake was more than 2% of the bodyweight of the animals, which was at least partially a result of a presence of browse and good quality lucerne hay in the diet, in addition to low-starch pellets and meadow hay. Collectively, this study showed that bongo, and most likely other browsing ruminants, can be maintained on a diet without starchy foods and produce, at least when good quality roughage is fed and the diet is supplemented with low-starch pellets.

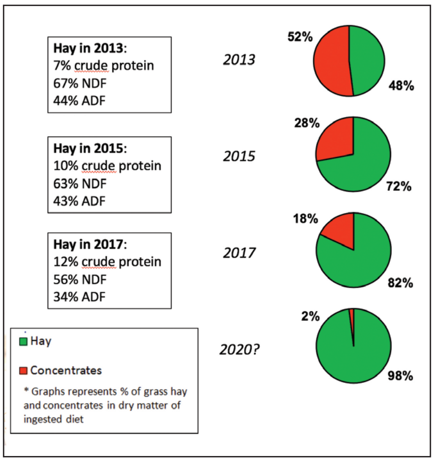

Figure 4: Changes of the proportion of concentrates and hay in the diet for addax in Silesian Zoo over several years and the improvement of the quality of hay offered.

CONCENTRATE-FREE DIETS – FEAR OF THE UNKNOWN

Fruit-free diets for primates in human care is one of the most popular topics in the field of nutrition of zoo animals. Why should we not try concentrate-free diets for zoo ruminants? There are still a few issues to think about.

First, the lack of results of controlled studies. The zoo may fear that the removal of concentrates may starve the animals or affect their ability to reproduce. However, some studies and observations show that removal of concentrates (and produce) from diets for ruminants in human care did not cause any (at least visual) differences in terms of body condition or health. This includes many species of grazer, such as waterbuck (*Kobus ellipsiprymnus*), lechwe (*Kobus leche*), wildebeest (*Connochaetes taurinus*) and wild cattle species (*Bos spp*.), and some species of intermediate feeders, such as sitatunga (*Tragelaphus spekii*) and nilgai (*Boselaphus tragocamelus*).

Secondly, low acceptance of offered roughage. Choosing the optimal type of roughage for a particular species of ruminant is very important. In our studies, a low intake of structured feeds was often associated with a low quality of grass and legume hays (low-protein and high-fibre content). When the quality of roughage that was fed to ruminants in the Silesian Zoo in Poland was improved, the animals increased their intake. This, in turn, allowed for a reduction of the amount of concentrates that were fed. As a result, the proportion of concentrates in diets for ruminants in the Silesian Zoo decreased year by year (Figure 4). Also, offering a wide range of roughage (different types of hay, silage and browse) may improve the intake of these feeds, especially by browsers. However, for browsers, the most problematic group of ruminants, reduction of the amount of concentrates in the diet should be done with special caution, preferably over a longer period of time, and feed intake and body condition should be regularly monitored.

Thirdly, meeting the demand for minerals and vitamins. Using food pellets is in most cases the easiest way of ensuring that additional minerals and vitamins are fed to zoo ruminants, meaning that those foods should be considered as part of the diet.

CONCLUSION

Increasing the intake of roughage and decreasing the intake of concentrates and produce is probably the key to a healthy digestive tract in zoo ruminants, and thus a long life in human care. Studies show that it is possible to feed zoo ruminants a diet free of concentrates and produce (with mineral-vitamin supplements present in the diet). If so, why don't you try such a diet for ruminants in your zoo?

WHY SIZE MATTERS

THE EFFECT OF PELLET SIZE ON THE FEEDING BEHAVIOUR OF RING-TAILED LEMURS (*LEMUR CATTA*) AND RED RUFFED LEMURS (*VARECIA RUBRA*)

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Nutrition is an important aspect of animal husbandry. As well as meeting nutrient requirements, food presentation can have a considerable impact on welfare. Making it harder to obtain food stimulates foraging behaviour, randomising feeding times can reduce stereotypies, and giving whole rather than chopped vegetables can reduce aggression. Due to the potential benefits of food presentation, more research on this could improve animal husbandry.

For this study, the effect of differently sized pellets on the behaviour of lemurs was examined. Two species were used, an all-male group of nine ring-tailed lemurs and a breeding pair of red ruffed lemurs, both located at Paignton Zoo. Three different pellets were fed for three weeks each: (1) Dodson & Horrell (D&H) leaf-eater (28x7x7mm), (2) DK Zoological leaf-eater small (25x15x5mm), (3) DK Zoological leaf-eater large (60x30x10mm). The amount fed of both DK Zoological pellets was slightly less than the first pellet to match energy provision. It should be noted that the large pellet from DK Zoological was much larger than the others. During the testing period, the time spent feeding and the number of agonistic behaviours were recorded. Repeated measures ANOVAs were used to test whether the different pellets affected the lemurs' behaviour.

For both species the small DK Zoological pellet resulted in the longest feeding times. This difference was significant for both ring-tailed [$F(2,35)=55.86$, $p<0.001$] and red ruffed lemurs: [$F(2,40)=12.29$, $p<0.001$]. But the effect was much greater for the ring-tailed lemurs, for whom the D&H pellet resulted in the lowest feeding times. For the red ruffed lemurs, the DK Zoological large pellets resulted in the lowest feeding time, although this did not differ significantly from the D&H pellet.

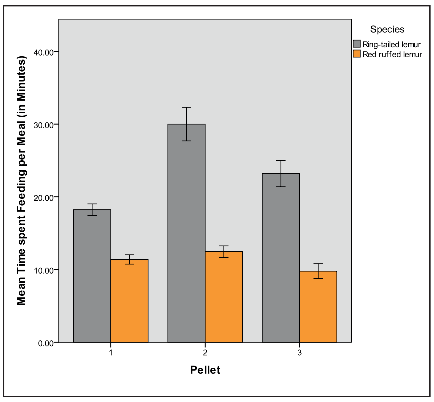

Figure 1: Average feeding times per pellet for ring-tailed and red ruffed lemurs.

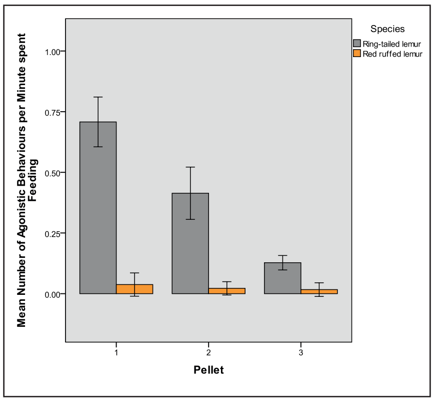

Figure 2: Average amount of agonistic behaviour per minute for ring-tailed and red ruffed lemurs during feeding time with different pellets.

Agonistic behaviour was hardly observed in the red ruffed lemurs, but differences were seen in agonistic behaviour in the ring-tailed lemurs when switching pellets. Agonistic behaviour was highest with the D&H pellets and lowest with the DK Zoological large pellets [$F(2,35)=48.88$, $p<0.001$]. For the red ruffed lemurs, the lowest amount of agonistic behaviour was also seen when feeding the large pellets, but this was not significant [$F(2,40)=0.38$, $p=0.684$].

The harder consistency yet small size of the small pellets from DK Zoological probably accounted for the highest feeding times. This is contrary to a study on whole versus chopped vegetables, which concluded that whole, and thus larger, vegetables increased the feeding time in primates. It is possible that the effect differs between fresh food and dry feeds. The amount of agonistic behaviour was greatly reduced as well when feeding DK Zoological pellets compared to the D&H pellet, on which the highest amount of agonistic behaviours was recorded. However, the lowest amount of agonistic behaviour was obtained by feeding the large pellets. This appeared to be because the lemurs could withdraw to a preferred spot to eat the pellets, reducing the number of conflicts over food. This is contrary to another study, where larger food resulted in more aggression. However, in that study, food was limited, whereas in this study it was not. The findings agree with a previous study at Paignton Zoo on whether or not vegetables should be chopped. Here, it also appeared that larger food allowed subordinates to withdraw and avoid aggression.

The small pellets appear to be the best option with the longest feeding time and low agonistic behaviours. However, to reduce aggression within a group, the large pellets may be the better option. Effects differed between species, which should be taken into account. It is likely that the larger size of the red ruffed lemurs made it easier for them to ingest the pellets, diminishing the effect of the different sizes.

In conclusion, pellet size can effectively alter both feeding time and aggression within a group, but effects are expected to be species-specific. Strategies to reduce aggression should consider the size of the feeds used on a situation-specific basis.

A NEW VIEW ON FEEDING

CARNIVORE FEEDING – THOUGHTS ON GOOD PRACTICE, FUTURE CHALLENGES AND VISIONS OF MEANINGFUL LIVES

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Carnivores, especially the large ones, are charismatic zoo animals. They are the object of scrutiny with respect to fundamental animal welfare (Mason *et al*., 2007), and it has been suggested that some species with large natural home ranges may not be suitable for zoo life (Clubb & Mason, 2003). The ironic impression is that a species famous for stereotypic pacing, the polar bear, is actually capable of 'sitting still' for serious proportions of its day in its huge home range.

A typical way for zoos to react to stereotypies is by focusing on 'enrichment' strategies. Here, I want to address the issue of offering a 'meaningful life', rather than 'enriching' an otherwise 'unenriched' life, using carnivore feeding – and hence, inadvertently, time-spending strategies, as an example.

My thoughts were triggered by an experience several years ago, when a circus put up its outside enclosure for tigers next to our garden. Observing the extreme opposites of intense anticipatory excitement, aggression and pacing prior to being 'on show' as well as the impressive relaxation, social rubbing, purring and calm after the show, I felt that this was something zoos do not provide: a highly stressful yet meaningful and anxiety-free event that structures the animals' day. When checking, I found that, as always, someone had made the same observation before (Krawczel *et al*., 2005).

1. Anticipation

My standard example goes like this: imagine you come home tonight, and your family surprises you with a Christmas tree and presents, demanding that you feel immensely enriched by this randomised, unpredictable experience. The point is that we want to look forward to things. Anticipation is part of the quality and meaning of life. This is increasingly being recognised in the zoo world (Watters, 2014). Studies show that anticipatory behaviour is a measure of how much animals value what they are anticipating (Clegg *et al*., 2018). By using unambiguous signals (beyond simple time schedules), the day of zoo animals can be filled with anticipation. If the anticipated event is more complex than 'I will get food', this may give the day meaning.

2. Feeding frequency

Carnivores differ dramatically in the relative size of their prey and hence in the number of kills they make each day (De Cuyper *et al*., 2019). Gorge-feeders need not eat every day, and they may miss the feeling of real gut-distending satiety and the social interactions linked to a large carcass if fed small amounts on a daily basis to meet daily requirements. Small prey-hunters, like wildcats, kill up to 10 times per day in their natural habitat (and not every hunt results in a kill). To feed them large amounts only once or twice a day creates an artificial situation. This is even worse in insect-feeders such as meerkats. Rather than feeding once-daily large chunks they can fight about, using machinery that can scatter granulated food 10 times a day would appear to be much more natural for them. For omnivorous bears, a number of feeding stations that release small portions of food on a random basis , which the bear has to check continually, provides a similar effect.

3. Complex food

Feeding whole prey that requires skilled manipulation will always be more challenging than feeding minced meat, filleted meat or skinned carcasses. For very small food (such as insects or granulates), the complexity is in the spatial distribution.

4. Making food difficult to get at

Measures to make animals work for their food includes hiding food in branch heaps, pole-feeding, feeding on top of a moving platform, pulley systems, counterweights or tug-of-war systems, feeding stations that release food at random, feeding in training situations such as pinniped shows, lure lines and many more (Law *et al*., 1997). Zoos have been very inventive in making animals work for their food.

5. Combining various methods

Combining various methods in a random order but with a clear signal for anticipation (so that the animal knows that 'today is neither pole-feeding day nor lure-line, but swinging-platform day') would represent an important mental structure for the day. One should not be complacent applying only one 'challenging' method per animal or enclosure.

6. Making failure an option

A polar bear won't necessarily stop stereotyping if you throw in food. Any challenging feeding methods only hold so much appeal – because at the end of the day, the animal knows it will get the food anyway. But will a polar bear stereotype, or express its typical sit-and-wait hunting behaviour, if it gets an anticipatory signal that tells it 'In the next three hours, food will appear for three seconds, and if you do not grab it, there may not be another chance for the day'?

Feeding will become meaningful

if the animal realises that it actually matters whether it is alert or not. Only if you know you can fail will you get the feeling of achievement. Providing the animal with this feeling is giving meaning, and it is only possible to do so by devising methods that will make the food disappear again, and quickly, if the predator is not alert. To my knowledge, the only such system ever published is a pulley designed to 'pull up' the prey out of reach if the a cheetah does not catch it within the first few seconds of pursuit (Williams *et al*., 1996). But even that publication does not say whether in the event of failure the animal goes hungry or gets the prey afterwards anyway.

Possible additional examples are tug-of-war systems that pull a carcass out of an enclosure if the animal (group) does not offer sufficient resistance; lure lines that leave the enclosure; a system of several slides for fish or other small prey that all go out of the enclosure again, but where it is unpredictable which slide the food will actually go down once released; or, of course, fancy systems that imitate an ice hole and bring up food in a seal-like manner. Devising intelligent feeding systems of this kind is a fascinating challenge for inventive zoo personnel.

The feeding systems should be coupled with clear signals that do not say that the system will be triggered 'in the next minute' but instead 'any time from now on'. It is important that the animal need not be alert all the time, but that the time where alertness is required is also not too short. The period of going hungry in case of failure should be adapted to the species – whole days for large cats, but an hour for a small cat. Failure-feeding can be complemented by days of challenge feeding (such as pole-feeding, swinging platforms). Depending on their individual character and disposition, some animals may need more variety and complex situations than others to stay alert.

Figure 1: Tiger feeding at Parken Zoo, Sweden – an easy method to make carcass-feeding more attractive and challenging. (*Courtesy of Anita Burkevica*.)

The point is not to expose the animal to the terror of random regimes (in which it may additionally fail). The point is to create situations, recognisable for the animal in anticipation, where the only thing that matters for success is the animal itself.

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FOOD FOR AGED ANIMALS

AGED ANIMALS IN ZOOS – CAN A DIET HELP TO IMPROVE WELFARE?

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DAVID TAN, WILDLIFE RESERVES SINGAPORE

By the time wild animals begin to age and slow down, their condition quickly begins to deteriorate. Older animals may move less quickly or be less agile, which makes them less likely to catch prey or more likely to be caught by a predator. Not many social animals would slow down the pace of the group to cater for older animals indefinitely. For this reason, there is very little documentation of senior animal biology – they rarely exist long enough to be studied. This is very different for animals under human care. As a testament to the increasing health and welfare provided in accredited zoos, our animals are living longer and longer. On the one hand this is good news, but on the other hand, it provides us with new ethical, welfare and health challenges that we are ill-equipped to tackle; ill-equipped not because we lack skills, but because there are very few references or models for how to tackle the recurring issues that we see in geriatric animals in zoos. Old age brings certain conditions and symptoms that we can now come to expect. Arthritis, kidney disease, obesity or wasting, ocular degeneration and dental disease are all expected to occur in geriatric individuals of certain taxa.

At Wildlife Reserves Singapore, we try to prevent the unnecessary culling of senile animals and therefore we pioneered a geriatric animal care programme. Every animal that reaches 75% of its published in-care lifespan is included in this programme. Animals that don't show any obvious health conditions related to age are classified as 'green'. This means they are entirely managed by the animal care team and given a diet change and supplements according to their taxa. Once the animal begins to show symptoms of health issues, they are classified as 'amber' and the veterinarians give a regular check-up and may or may not prescribe medication. Once the animal has shown obvious signs of slowing down and of old age, they are classified as 'red', which indicates a more palliative strategy, to ensure the animal enjoys the best welfare possible during its final stage of life. Quality of life assessments must be performed daily, and appropriate medications or painkillers may also be prescribed by the vets, along with more frequent checks. This plan shows the importance of a change in diet for geriatric animals. Once the animal reaches the red or even the amber stage, the influence of nutrition to help ease health issues may be limited. The usefulness of the geriatric diet really lies in the green phase, in the potential of nutrition as preventative medicine.

EATING TO LIVE

Nutrition is rarely used as preventative medicine, but in this case, we know exactly which symptoms different taxa show in response to old age. This means that preventative medicine should be quite straightforward, and should address the causes that lead to the degeneration of this particular organ or metabolic system. This has not been attempted yet in wild animals in human care, and validation of the use of specific diets in delaying or preventing certain age-related symptoms will take years to prove, but a starting point may be found with our domestic animals. For animals used in agriculture, such as cows, sheep, goats and pigs, there is also not a lot of information about care during old age because they never make it there. Once they are of a suitable weight, they are slaughtered. Pets and hobby animals were the only resources available: dogs for omnivores, cats for carnivores, rats for rodents, rabbits for lagomorphs, falcons for raptors, horses for perissodactyls, a limited amount of sheep literature for ruminants. This, along with some educated guesses, allowed for the creation of the geriatric diets.

Arthritic conditions are particularly debilitating to animals under human care. They are painful and affect an animal more or less at all times of the day and night; the animals visibly

Veterinary Scoring				
	Average Week 0	+/- SD	Average Week 12	+/- SD
Lameness	2.4	0.5	0.5	0.4
	2.2	0.4	1	0.9
	Keeper Scoring		+/- SD	
Activity	1.6		0.3	
Limping	1.6		0.2	
Rising from rest	1.5		0.3	
Stiffness	1.8		0.2	
Walking	1.7		0.2	

Table 1: Average scores across species from the visual assessments of the veterinarians for increase in activity and decrease of unwanted behaviour (1 = ideal 5 = terrible) and the animal care team (scale of improvement where 1 is constant improvement, 2 is no change and 3 is constant worsening) and their respective standard deviations (+/- SD).

slow down and are less active, and when they do move, movements become robotic, which visitors associate with pain. These conditions affect most geriatric animals, are painful and drastically reduce the exhibit value of our animals. Luckily, preventative medicine through nutrition is extremely effective at tackling this issue.

Through trials at WRS, we were able to determine an effective mix of supplements aimed at reducing symptoms of arthritis in birds of prey, carnivores, artiodactyls, perissodactyls and primates. However, our assessment methods were somewhat subjective. Using the methods of Roush *et al*., (2010), we had two sets of data: one from the veterinary team and one from the animal's keeper team. The veterinary team scored the animal at the start of the supplementation, and every four weeks after that for 12 weeks. They scored the following, from good (1) to bad (5); lameness, weight bearing, body condition and pelage quality. The keeper team had different criteria in their assessments. They scored the animal at the beginning of the supplementation and every two weeks thereafter for 12 weeks. They scored a number of behaviours as either 1 (better than last week), 2 (same as last week) or 3 (worse than last week). Activity level, aggression, climbing, jumping, lagging behind, limping, rising from rest, running, stiffness and walking were all scored. Thus an average score of 1 means there was constant improvement week on week, but the improvement itself cannot be quantified using this method. At the opposite end, a score of 3 would mean a progressive worsening of the condition week on week. The veterinary approach helps to give this method more objectivity by scoring particular movements. If the keeper scores strongly disagreed with the veterinary score, the data set for this animal was discarded.

Ruminants received calcium, a fermentable fibre and fish oil (DHA and EPA omega-3 fatty acids) supplements; birds of prey received antioxidants, L-carnitine, taurine, calcium and omega-3; carnivores and omnivores received vitamin E and omega-3, and 20% of their red meat was transitioned to chicken; perissodactyls received a beet pulp product, calcium, pectin, ascorbic acid, vitamin B complex and omega-3; and primates received oats, egg whites, pectin, calcium, omega-3, carotenoids and vitamin E and C. Results showed an overall increase in activity and a decrease in arthritis-related behaviours such as lameness, weight bearing, limping and difficulty in rising from rest (Table 1).

Not every supplement was targeting the symptoms of arthritis, and because supplements were always given together, it is impossible to determine which ones have an effect on arthritis. However, two supplements were given to every animal, calcium and omega-3. For animal-based omega-3 supplements (DHA and EPA, usually from fish, krill or green-lipped mussels), there is strong evidence for a beneficial effect in reducing the symptoms of arthritis in a variety of domestic animals (Bui & Bierer, 2003; Manhart *et al*., 2009; Yamka *et al*., 2006). Its usefulness seems also to extend to wild animals under human care. The ratio of different fatty acids is also crucial, not only their overall amount in the diet.

DAVID TAN, WILDLIFE RESERVES SINGAPORE

Most foods fed to domesticated and wild animals in human care are highly concentrated in omega-6 fatty acids rather than omega-3. With the ideal ratio being somewhere around 5:1 (omega-6 to omega-3), this makes supplementation almost essential (Kearns *et al*., 1999). Another level of complexity arises from the different biological activity of plant-based omega-3 (ALA) and the animal-based omega-3. The conversion of ALA into the active forms of EPA and DHA are different in every species and largely variable based on genetics. Using dogs as an omnivorous model and cats as the carnivorous model, omnivores would only be able to convert up to 10 per cent and carnivores even less (Bauer, 2008). Herbivores would presumably be better at this conversion; however, since we know the active form is EPA and DHA, adding these supplements directly into the diet is much more beneficial. Our grazer pellets already contain linseed, the most popular source of ALA omega-3, and yet with the addition of fish oil, we saw a significant reduction in arthritis symptoms.

Our supplements had a significantly positive effect on reducing the symptoms of arthritis in geriatric zoo animals. Although our sample size is limited and we still have to monitor the progress of these senile animals towards even older age, our observations lead us to believe that these animals enjoy a better quality of life and higher levels of welfare than previously, as well as providing more exhibit value than previously. Our continuing research will be to identify the most effective dosage for different taxa, and validate it with a larger sample size.

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