Challenges in zoo animal nutrition

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Belo Horizonte 2019
We feed zoo animals …

1. … and meet nutrient requirements or cause deficiencies

2. … and influence their behaviour

3. … and we tell a story
   - to keepers and zoo personnel
   - to visitors
What’s in an apple?

- 85% water
- 10% sugar
Sugars and other nutrients in produce (of fruits and vegetables)

All values expressed as g/kg wet weight, unless otherwise stated.

<table>
<thead>
<tr>
<th>Fruits</th>
<th>Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Banana</strong></td>
<td><strong>Carrot</strong></td>
</tr>
<tr>
<td>Musa acuminata</td>
<td>Daucus carota</td>
</tr>
<tr>
<td>204 gram sugar</td>
<td>45 gram sugar</td>
</tr>
<tr>
<td><strong>Apple</strong></td>
<td><strong>Sweet potato</strong></td>
</tr>
<tr>
<td>Malus domestica</td>
<td>Ipomoea batatas</td>
</tr>
<tr>
<td>86 gram sugar</td>
<td>32 gram sugar</td>
</tr>
<tr>
<td><strong>Orange</strong></td>
<td><strong>Celery</strong></td>
</tr>
<tr>
<td>Citrus × sinensis</td>
<td>Apium graveolens</td>
</tr>
<tr>
<td>56 gram sugar</td>
<td>24 gram sugar</td>
</tr>
<tr>
<td><strong>Kiwi</strong></td>
<td><strong>Spinach</strong></td>
</tr>
<tr>
<td>Actinidia deliciosa</td>
<td>Spinacia oleracea</td>
</tr>
<tr>
<td>52 gram sugar</td>
<td>1 gram sugar</td>
</tr>
<tr>
<td><strong>Papaya</strong></td>
<td><strong>Endive</strong></td>
</tr>
<tr>
<td>Carica papaya</td>
<td>Cichorium endivia</td>
</tr>
<tr>
<td>27 gram sugar</td>
<td>0 gram sugar</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dry</th>
<th>NDF</th>
<th>ADF</th>
<th>Crude Protein</th>
<th>Fat</th>
<th>Ca</th>
<th>P</th>
<th>Mg</th>
<th>Fe</th>
<th>Crude Fat</th>
<th>Vit. A</th>
<th>Vit. C</th>
<th>Vit. E</th>
<th>α-TE</th>
<th>Vit. A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fruits</strong></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Banana</td>
<td>4.1</td>
<td>19.8</td>
<td>8.4</td>
<td>0.70</td>
<td>0.09</td>
<td>0.16</td>
<td>0.30</td>
<td>0.05</td>
<td>0.12</td>
<td>207</td>
<td>5.7</td>
<td>0.003</td>
<td>5.5</td>
<td>-</td>
</tr>
<tr>
<td>Apple</td>
<td>4.1</td>
<td>0.4</td>
<td>6.8</td>
<td>0.11</td>
<td>0.13</td>
<td>0.24</td>
<td>0.23</td>
<td>0.05</td>
<td>0.20</td>
<td>115</td>
<td>2.0</td>
<td>0.001</td>
<td>5.5</td>
<td>-</td>
</tr>
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<td>Orange</td>
<td>4.1</td>
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<td>0.001</td>
<td>5.5</td>
<td>-</td>
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<tr>
<td><strong>Vegetables</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>2.5</td>
<td>10.7</td>
<td>0.4</td>
<td>0.05</td>
<td>0.05</td>
<td>0.10</td>
<td>0.12</td>
<td>0.02</td>
<td>0.08</td>
<td>207</td>
<td>5.7</td>
<td>0.003</td>
<td>5.5</td>
<td>-</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>2.5</td>
<td>0.4</td>
<td>6.8</td>
<td>0.11</td>
<td>0.13</td>
<td>0.24</td>
<td>0.23</td>
<td>0.05</td>
<td>0.20</td>
<td>115</td>
<td>2.0</td>
<td>0.001</td>
<td>5.5</td>
<td>-</td>
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<tr>
<td>Celery</td>
<td>2.5</td>
<td>0.4</td>
<td>6.8</td>
<td>0.11</td>
<td>0.13</td>
<td>0.24</td>
<td>0.23</td>
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<td>5.5</td>
<td>-</td>
</tr>
<tr>
<td>Endive</td>
<td>2.5</td>
<td>0.4</td>
<td>6.8</td>
<td>0.11</td>
<td>0.13</td>
<td>0.24</td>
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<td>-</td>
</tr>
</tbody>
</table>

All values expressed as g/kg wet weight, unless otherwise stated.
... is healthier than ...

... is healthier than ...
Don’t believe names, think for yourself

• ‘Frugivores’ are adapted to wild fruits but not to commercial produce that has been bred for centuries to please the human palate!

• A large number of nutritional analyses document that ‘wild fruit’ contain more fibre and less sugar than commercially available fruit (that is the product of selective breeding to please human taste).
# The Feeding and Nutrition of Omnivores with Emphasis on Primates

**Olav T. Ofstedal and Mary E. Allen**

## Table 14.5. Comparison of Some Foods Eaten by Primates in Zoos and in the Wild

<table>
<thead>
<tr>
<th>Food type</th>
<th>Dry matter</th>
<th>Protein</th>
<th>Fiber fractions</th>
<th>Ca</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>NDF</td>
<td>ADF</td>
<td>AL</td>
</tr>
<tr>
<td>Market produce used in primate diets&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apples</td>
<td>12.8</td>
<td>2.3</td>
<td>17.4</td>
<td>12.6</td>
<td>3.8</td>
</tr>
<tr>
<td>Green beans</td>
<td>10.7</td>
<td>17.9</td>
<td>28.0</td>
<td>25.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Cabbage</td>
<td>8.9</td>
<td>14.7</td>
<td>20.6</td>
<td>21.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Carrots</td>
<td>12.2</td>
<td>7.7</td>
<td>15.2</td>
<td>16.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Kale</td>
<td>12.3</td>
<td>32.5</td>
<td>19.3</td>
<td>24.7</td>
<td>4.6</td>
</tr>
<tr>
<td>Foods eaten in the wild by red howler monkeys&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flowers</td>
<td>25.1</td>
<td>14.4</td>
<td>50.6</td>
<td>35.8</td>
<td>17.1</td>
</tr>
<tr>
<td>Fruits</td>
<td>23.7</td>
<td>7.0</td>
<td>53.8</td>
<td>35.2</td>
<td>16.6</td>
</tr>
<tr>
<td>Mature leaves</td>
<td>36.5</td>
<td>16.6</td>
<td>57.2</td>
<td>40.5</td>
<td>20.4</td>
</tr>
<tr>
<td>Young leaves</td>
<td>32.2</td>
<td>21.2</td>
<td>54.4</td>
<td>36.4</td>
<td>21.1</td>
</tr>
</tbody>
</table>
if you want to ‘copy’ wild fruit, you have to feed green, leafy vegetables
What is your story?
What is your story?

“We show you that you can maintain wild animals in human care with diets that do not resemble the ones they eat in the wild.”
What is your story?
What is your story?

“We are concerned with conservation and welfare but we think it has nothing to do with feeding natural diets.”
What is your story?
What is your story?

“Nature sucks. Let us rather do something unnatural – it is much more fun.”
What is your story?
What is your story?

“Hurray for Chiquita!”
What is your story?
What is your story?

At our zoo, we show you that it is ok to treat animals like cartoon characters.

And by the way, we justify it by saying conservation is important.
What is your story?
Giraffe activity budgets

Influence of ration composition on nutritive and digestive variables in captive giraffes (*Giraffa camelopardalis*) indicating the appropriateness of feeding practice

I. Gussek¹ | C. Große-Brinkhaus¹ | K.-H. Südekum¹ ID | J. Hummel²

What is your story?

“It is our aim to feed our animals a diet that consists of about 0.5% natural diet items.”
This represents app. 1.5 kg edible browse (= 380 g dry matter) per 5 animals ... who would eat 18 kg DM /d each, i.e. 0.4 % of natural intake.
What is your story?
Chimpanzee R/R
An analysis of regurgitation and reingestion in captive chimpanzees

Kate C. Baker a, *, Stephen Phillip Easley b


of cagemates or housing history; nor were sex differences detected. Meal composition was not found to effect the time devoted to R/R. Statistical tests did show a strong positive relationship between rates of R/R and elapsed time since feeding. These results suggest that increasing meal frequency or providing consistently available edible material may prove more broadly effective than altering meal composition. Temporal distributions of R/R differed from those of abnormal old male) (Morgan et al., 1993). That study found that R/R occurred within minutes of each meal, and was most frequent following meals consisting of fruit. Reductions in R/R occurred during behavioral training sessions and when more browse was provided.
What is your story?

We get our animals hooked on sugar so they always come back to sugar daddy...
Fatter animal are more difficult to kidnap
A Survey of Diabetes Prevalence in Zoo-housed Primates

C. W. Kuhar,* G. A. Fuller, and P. M. Dennis

Nearly 30% of responding institutions reported at least one diabetic primate in their current collection. Although the majority of reported cases were in Old World Monkeys (51%), all major taxonomic groups were represented. Females represented nearly 80% of the diagnosed cases. A wide variety of diagnosing, monitoring, and treatment techniques were reported. It is clear from these results diabetes should be considered prominently in decisions relating to diet, weight and activity levels in zoo-housed primates, as well as discussions surrounding animal health and welfare.

Hypertension Increases With Aging and Obesity in Chimpanzees (Pan troglodytes)

John J. Ely,* Tony Zavaskis, and Michael L. Lammey
Zoo Biology 32: 79–87 (2013)

Cardiovascular disease is a primary cause of morbidity and mortality in captive chimpanzees. For females, obesity was a significant determinant of BP.
Figure 1. Frequency of dental issues identified or treatment required for six species of primate at Paignton Zoo Environmental Park before and after the initiation of diet improvements to reduce dietary sugar (March 2003).
Diet review and change for monkeys at Paignton Zoo Environmental Park

Journal of Zoo and Aquarium Research 1(2) 2013

Amy Plowman

Figure 2. Body weights of a group of Diana monkeys at Paignton Zoo Environmental Park following a diet review that prompted a change from a fruit-based to a vegetable-based diet. The removal of all fruit occurred in April 2007; other changes were completed in September 2007 immediately before the first weights were obtained.
Aggression and self-directed behaviour of captive lemurs (Lemur catta, Varecia variegata, V. rubra and Eulemur coronatus) is reduced by feeding fruit-free diets

Stephanie Britt¹, Katherine Cowlard¹, Kathy Baker² and Amy Plowman³*

Journal of Zoo and Aquarium Research 3(2) 2015
“We feed our monkeys fruit so that they have something to fight about.”
Development of zoo feeding regimes

- Concepts from agriculture
  - (production animals, use production potential)
  - Human consumption habits

- Copying natural diets

- Avoid diseases
  - Use adaptation potential
  - Teaching biological knowledge
Man-made diets: too little fibre

- Human nutrition → gut health
- Pigs → piglet diarrhoea
- **Beef cattle/ Dairy cattle**
- Riding horses → crib biting
- Dogs/ Cats → faeces consistency
- Zoo animals → obesity
Fibre content depends on intended use

<table>
<thead>
<tr>
<th>Use</th>
<th>Fibre content*</th>
<th>Longevity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef cattle</td>
<td>12 %DM</td>
<td>app. 2 years</td>
</tr>
<tr>
<td>Dairy cattle</td>
<td>18 %DM</td>
<td>app. 4 years</td>
</tr>
<tr>
<td>Feral cattle</td>
<td>30 %DM</td>
<td>app. 25 years</td>
</tr>
</tbody>
</table>

*historical recommendations for ration design
Zoo nutrition problems
- historical development
The classic problem repertoire

Carnivore → Red meat → Calcium deficiency
The classic problem repertoire

Carnivore $\rightarrow$ Red meat $\rightarrow$ Calcium deficiency
The classic problem repertoire

Carnivore → Red meat + Calcium deficiency

Dental calculus, obesity, behavioural deficiencies
The classic problem repertoire

Carnivore → Red meat → Calcium deficiency

Dental calculus, obesity, behavioural deficiencies
The classic problem repertoire

Carnivore → Red meat → Calcium deficiency

- Dental calculus
- Obesity
- Behavioural deficiencies
The classic problem repertoire

Carnivore → Red meat → Calcium deficiency

- Dental calculus;
- Obesity;
- Behavioural deficiencies

+ adequate presentation = enrichment !!
Primate  Fruits & vegetables  Calcium deficiency

The classic problem repertoire
The classic problem repertoire

Primate $\rightarrow$ Fruits & vegetables $\rightarrow$ Calcium deficiency

+
The classic problem repertoire

Primate → Fruits & vegetables → Calcium deficiency

+ → Obesity, caries, aggression, abnormal behaviour
The classic problem repertoire

Primate → Fruits & vegetables → Calcium deficiency

- Obesity, caries, aggression, abnormal behaviour.
The classic problem repertoire

Primate → Fruits & vegetables → Calcium deficiency

+ Obesity, caries, aggression, abnormal behaviour

adequate presentation = enrichment !!
The classic problem repertoire

Herbivore → Hay, fruits & grains → Vitamin E- and calcium deficiency
The classic problem repertoire

Herbivore → Hay, fruits & grains → Vitamin E and calcium deficiency
The classic problem repertoire

Herbivore → Hay, fruits & grains → Vitamin E and calcium deficiency
The classic problem repertoire

Herbivore → Hay, fruits & grains → Vitamin E and calcium deficiency + Obesity, malfermentation, abnormal behaviour
Herbivore → Hay, fruits & grains → Vitamin E and calcium deficiency → Obesity, malfermentation (acidosis), abnormal behaviour
Herbivore ➔ Hay, fruits & grains ➔ Vitamin E and calcium deficiency

Obesity, malfermentation (acidosis), abnormal behaviour

+ adequate presentation = enrichment !!
Not every herbivore likes grass hay


**Mule deer** Cahart (1943), Doman and Rasmussen (1944), Nagy et al. (1969), Schoonveld et al. (1974)

**Roe deer** Dissen (1983)

**Chinese water deer** Hofmann et al. (1988)

**Duiker** Cowan (1982), Luginbuhl et al. (1991), Van Soest et al. (1995)

**Reindeer** Eriksson and Schmekel (1962), Kurkela (1976), Valtonen et al. (1983)

**Eland** Hofmann (1973, p. 40), Miller et al. (2010)

**Kudu** Miller et al. (2010)
Not every herbivore likes grass hay

from Foose (1982)
Different enamel ridge pattern on molars

from Kaiser et al. (2010)
Fecal particle size in herbivores

from Hummel et al. (2008)
Molars in perissodactyls
Fecal particle size in herbivores

from Hummel et al. (2008)
Not every herbivore likes grass hay

• Just because giraffes, tapirs or gorillas do not eat grass hay does not mean they do not need a high-fibre diet

• (they also do not eat fish and nevertheless require protein)

• it is a husbandry challenge to provide a roughage or high-fibre diet that these animals accept
Not every herbivore likes grass hay
Hypsodonty
Hypsodonty

Hummel (unpubl.)
A comparison of observed molar wear rates in extant herbivorous mammals

John Damuth¹ & Christine M. Janis²

Helsinki 7 April 2014
Phytoliths

32 μm

400x

1000x

© W.P. Armstrong 2005
Free-ranging vs. captive giraffes

from Clauss et al. (2007)
Basic feeding approach

Animal group ➔ Agriculture / human-taste diets ➔ Classic deficiencies
Basic feeding approach

Animal group → Agriculture / human-taste diets + supplement → Classic deficiencies
Basic feeding approach

Animal group → Agriculture / human-taste diets + supplement → Classic deficiencies

‘Civilisation diseases’
(obesity, malfermentation),
abnormal behavior
(stereotyped, aggression)
Basic feeding approach

$\text{Animal group}$ → $\rightarrow \text{Agriculture / human-taste diets}$ + $\rightarrow \text{supplement}$

$\rightarrow \rightarrow \text{Diets that resemble natural diets in structure and nutrient composition}$

$\rightarrow \rightarrow \rightarrow \rightarrow \text{Classic deficiencies}$

$\rightarrow \rightarrow \rightarrow \rightarrow \text{‘Civilisation-diseases’: (obesity, malfermentation)}$

$\rightarrow \rightarrow \rightarrow \rightarrow \text{abnormal behavior: (stereotypies, aggression)}$
Basic feeding approach

Animal group

Agriculture / human-taste diets + supplement

Classic deficiencies

‘Civilisation diseases’

(obesity, malfermentation),
abnormal behavior
(stereotypies, aggression)

Diets that resemble natural diets in structure and nutrient composition + adequate presentation = enrichment !!
Basic feeding approach

Animal group

- Agriculture / human-taste diets + supplement
- Classic deficiencies

- ‘Civilisation diseases’ (obesity, malfermentation),
  abnormal behavior (stereotypies, aggression)

- Diets that resemble natural diets in structure and nutrient composition
  + adequate presentation = enrichment !!

Enrichment should **not** be **the addition of something**
(like human-taste items) but **the presentation of the diet an**
a **challenging and meaningful** way!
Enclosure design and use
Enclosure design and use
Enclosure design and use
Enclosure management = enrichment
Changing a bear diet
Bears at a Zoo were considered obese when compared to reported body mass for species (male: 180 vs. 140 kg, female: 115 vs. 75 kg)

Diet offered contained 2x the amount of ME (calculated as for dogs) compared to estimated requirements at ideal body weight.

**Challenge:** feeding a group where some individuals should lose weight, some should keep weight, and one should continue to grow!
Amount of food was reduced (to what was calculated as the total requirement on ideal body weight).
Bread was excluded, fruits reduced, additional vegetables introduced.
Regular weighing (every second week).

The most important task was to have all personnel involved agree on goals of weight loss and diet change to a more ‘natural’ diet (in terms of nutrient composition).
Changing a bear diet

*obese male: weight loss; left the zoo at this point*
Changing a bear diet

- **Obese female: weight loss**
- **Normal females: constant weight**
- **Growing female: growth to normal weight**

Chart showing body mass (kg) over time:

- **Sisa**
- **Cocha**
- **Cashu**
- **Huanca**

Date range: 15.1.08 to 25.3.10
The most important accomplishment is the creation of a situation where everyone involved now considers regular weighing, and constant adjustment of diet amounts based on the results of weighing, a normal procedure.
Seasonal body mass changes and feed intake in spectacled bears (*Tremarctos ornatus*) at Zurich Zoological Garden

Journal of Zoo and Aquarium Research 4(3) 2016

Kerstin Gerstner¹, Annette Liesegang¹, Jean-Michel Hatt², Marcus Clauss²* and Cordula Galeffi³
What is your story?