The natural diet and digestive anatomy & physiology of elephants - consequences for feeding regimes in captivity

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Elephant Workshop, Zurich 2018
Natural diet of elephants

• Elephants are strict herbivores

• Elephants consume varying proportions of grass and browse

• Due to their large absolute requirements, elephants cannot afford to be selective and ingest (comparatively) low-quality forage
Natural diet of elephants

Thure E. Cerling · John M. Harris · Meave G. Leakey

Browsing and grazing in elephants:
the isotope record of modern and fossil proboscideans

**Elephant natural diets: nutrient composition**

- **Crude protein**: 8-12% DM
- **Crude fat**: 2-5% DM
- **Crude ash**: 10-20% DM
- **Crude fibre**: 35-47% DM
- **NDF**: 52-73% DM
- **ADF**: 38-52% DM
- **ADL**: 9-21% DM
- **Calcium**: 0.02-5.72% DM

Kitum cave, Mt. Elgon National Park, Kenya
Dental apparatus

African elephant
*Loxodonta africana*

Asian elephant
*Elephas maximus*
Dental apparatus
Dental apparatus
A recent finding in European zoo elephants

Schiffmann et al. (in preparation)
Digestive tract

Zebra
(Equus burchelli)
Body Length: 2 m

Rhinoceros
(Diceros bicornis)
Body Length: 3.2 m

African Elephant
(Loxodonta africana)
Body Length: 3.3 m

from Stevens & Hume (1995)
Digestive tract

Zebra
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(Loxodonta africana)
Body Length: 3.3 m

from Stevens & Hume (1995)
Digestive tract

from Clauss et al. (2007)
Short retention times

No consistent increase of mean retention time (MRT) with body size

Data from Foose (1982)
Low digestibility

No consistent increase of apparent digestibility (aD) with body size

Data from Foose (1982)
Low digestibility

Elephants have lower digestibilities than horses on comparable diets

from Clauss et al. (2003)
Retention and digestion do not match?

Horse: Pagan et al. (1998), elephants: Clauss et al. (2003), Indian rhinos: Clauss et al. (2005)
Don’t forget particle size!

Mean particle size (MPS) is higher in elephants and rhinos than in horses

BM (kg) vs. MPS (mm)

Data from Fritz et al. (2009)
Don’t forget particle size!

Mean particle size (MPS) is higher in elephants and rhinos than in horses.

data from Clauss et al. (2015)
Asian elephants achieve slightly higher digestion coefficients ...
Asian elephants achieve slightly higher digestion coefficients ... at slightly longer mean retention times.

Hackenburger (1987)
Digestive physiology can limit intake

\[ \text{MRT} = a - b \text{DMI} \]
Digestive physiology can limit intake

\[
\text{MRT} = a - b \text{DMI}
\]
\[
\alpha D \text{DM} = c + d (1 - e^{-f \text{MRT}})
\]
\[
d\text{DMI} = \text{DMI} \times \alpha D \text{DM} / 100
\]

\[
\text{DMI} \sim d\text{DMI}
\]

Clauss et al. (2007)
Summary

Elephants eat a lot of food (which fills most of their day) which they do not digest very well. High intake - low digestibility strategy with behavioural and physiological adaptations to a high food intake.

“Elephants want to eat as much as they can”
The elephants’ strategy

Elephants eat a lot of food (which fills most of their day) which they do not digest very well. High intake - low digestibility strategy with behavioural and physiological adaptations to a high food intake.

... predisposes them, in the presence of diet items that are more digestible than their natural diet

... to either boredom

... or obesity
... to either boredom

suggest stress and/or obesity as likely causes.

... or obesity
A survey of African (*Loxodonta africana*) and Asian (*Elephas maximus*)
elephant diets and measured body dimensions compared to their
estimated nutrient requirements
K. Ange, S.D. Crissey, C. Doyle, K. Lance, H. Hintz
Proceedings of the 2001 Conference of the AZA Nutrition Advisory Group 4:5-14

<table>
<thead>
<tr>
<th></th>
<th>Mean adult female body mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Free-range</td>
</tr>
<tr>
<td></td>
<td>2720</td>
</tr>
<tr>
<td></td>
<td>2800</td>
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</tbody>
</table>
Fecundity and population viability in female zoo elephants: problems and possible solutions

R Clubb, M Rowcliffe, P Lee, KU Mar, C Moss and GJ Mason


<table>
<thead>
<tr>
<th>Group/measure</th>
<th>Population</th>
<th>Population difference</th>
<th>Data source/notes</th>
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<tbody>
<tr>
<td></td>
<td>In situ</td>
<td>Zoo</td>
<td></td>
</tr>
<tr>
<td>Birth weight</td>
<td>89.5 (± 6.3) kg (n = 5)</td>
<td>102.1 (± 9.6) kg (n = 63)</td>
<td>$F_{1,66} = 8.32, P = 0.005$</td>
</tr>
<tr>
<td></td>
<td>74.0 kg (n = 6)</td>
<td>105.6 kg (n = 40)</td>
<td>Reported in paper as significant</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>118.8 kg (n = 7)</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Hayssen et al 1993

Kurt & Mar 1996 (sexes pooled)

ISIS 2002 (females only)
Risk of high birth weight?


Slide courtesy of Kibby Treiber
Elephant body mass

Schiffmann et al. (in prep.)
Fast growth

Data from Kurt (1998) & Kurt (2005)

Slide courtesy of Kibby Treiber
Female elephant body mass & breeding

Schiffmann et al. (in prep.)
Faster life cycle in zoos?

(Mar, 2002; Clubb, 2009; Taylor, 1998)

Slide courtesy of Kibby Treiber
Body condition monitoring

Hatt & Clauss (2006), Schiffmann et al. (2018)
Body condition monitoring

Diagnostic characters pertaining to scores in

1. Ribs (shoulder to pelvis) visible, some ribs prominent (spaces in between sunken in)
2. Me ribs visible (spaces in between not sunken in), shoulder and pelvic girdles
What’s in an apple?

- 85% water
- 10% sugar
### Fruits

<table>
<thead>
<tr>
<th></th>
<th>Available carbohydrate %</th>
<th>Calcium %</th>
<th>Phosphorus %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
<td>4.9</td>
<td>0.0</td>
<td>3.1</td>
</tr>
<tr>
<td><strong>Rest</strong></td>
<td>2.3</td>
<td>0.1</td>
<td>1.7</td>
</tr>
</tbody>
</table>

### Vegetables

<table>
<thead>
<tr>
<th></th>
<th>Available carbohydrate %</th>
<th>Calcium %</th>
<th>Phosphorus %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
<td>7.2</td>
<td>0.0</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Rest</strong></td>
<td>7.1</td>
<td>0.1</td>
<td>3.1</td>
</tr>
</tbody>
</table>

## 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>Fruit/Flora</th>
<th>MJ Energy</th>
<th>Carbohydrates</th>
<th>Protein</th>
<th>Fat</th>
<th>Ca</th>
<th>P</th>
<th>Mg</th>
<th>Fe</th>
<th>Vit. A</th>
<th>Vit. C</th>
<th>Vit. E</th>
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<tbody>
<tr>
<td>Papaya</td>
<td>2.5</td>
<td>18.5</td>
<td>12.9</td>
<td>4.7</td>
<td>0.32</td>
<td>0.1</td>
<td>0.07</td>
<td>0.28</td>
<td>31.4</td>
<td>0.02</td>
<td>5.5</td>
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<td>Kiwi</td>
<td>1.5</td>
<td>12.7</td>
<td>9.7</td>
<td>8.3</td>
<td>0.03</td>
<td>3.9</td>
<td>0.002</td>
<td>0.006</td>
<td>44.2</td>
<td>0.004</td>
<td>5.5</td>
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<tr>
<td>Orange</td>
<td>2.0</td>
<td>17.3</td>
<td>9.9</td>
<td>6.6</td>
<td>0.007</td>
<td>0.1</td>
<td>0.006</td>
<td>0.006</td>
<td>197</td>
<td>0.007</td>
<td>29</td>
</tr>
<tr>
<td>Celery</td>
<td>1.4</td>
<td>10.7</td>
<td>6.6</td>
<td>9.7</td>
<td>0.005</td>
<td>0.3</td>
<td>0.004</td>
<td>0.009</td>
<td>1030</td>
<td>0.005</td>
<td>3.5</td>
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<td>Sweet potato</td>
<td>1.8</td>
<td>15.6</td>
<td>9.7</td>
<td>9.7</td>
<td>0.005</td>
<td>0.3</td>
<td>0.004</td>
<td>0.009</td>
<td>3730</td>
<td>0.005</td>
<td>3.5</td>
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<tr>
<td>Bananas</td>
<td>1.8</td>
<td>11.4</td>
<td>7.8</td>
<td>7.8</td>
<td>0.005</td>
<td>0.3</td>
<td>0.004</td>
<td>0.009</td>
<td>14.2</td>
<td>0.005</td>
<td>3.5</td>
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<td>Spinach</td>
<td>1.0</td>
<td>5.7</td>
<td>4.3</td>
<td>4.3</td>
<td>0.005</td>
<td>0.3</td>
<td>0.004</td>
<td>0.009</td>
<td>26.2</td>
<td>0.005</td>
<td>3.5</td>
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<td>Carrots</td>
<td>0.9</td>
<td>5.2</td>
<td>3.2</td>
<td>3.2</td>
<td>0.005</td>
<td>0.3</td>
<td>0.004</td>
<td>0.009</td>
<td>14.2</td>
<td>0.005</td>
<td>3.5</td>
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<tr>
<td>Green beans</td>
<td>0.8</td>
<td>4.3</td>
<td>2.6</td>
<td>2.6</td>
<td>0.005</td>
<td>0.3</td>
<td>0.004</td>
<td>0.009</td>
<td>14.2</td>
<td>0.005</td>
<td>3.5</td>
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</table>

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Captive elephants’ diets

Roughages with low nutritional quality as the staple diet item (mature hay, straw, branches, browse). Variety in these items is the key.

Meet higher nutrient requirements ideally by feeding higher-quality roughage to the respective animals.

Use fresh/ensiled forages (not ad libitum).

Use pelleted feed (not grain-based, high fibre) for securing mineral supply.

Avoid bread, grain, fruits.
Consider offering salt periodically.
Captive elephants’ diets

Offer diet

- so that animals have something to feed on the whole day
- in a mechanically challenging way
- in a spatial distribution that stimulates activity
- with enrichment devices

... without breaching the trust that develops between elephants and keepers.
... monitor body weight/body condition regularly.