Feeding ruminants

Marcus Clauss
Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty
University of Zurich
mclauss@vetclinics.uzh.ch
Nutrition-related problems in captive giraffe

- phytobezoars
- rumen acidosis
- partial ruminal papillation loss
- “peracute mortality syndrome”
Phytobezoars


• aggregation of fibrous plant particles
• in lower stomach chambers
• associated with high-fibre diets or grass ingestion
Rumen acidosis


- high concentrate/low fibre diet
- increase in lactic acid producing bacteria
- drop in rumen pH
- unfavourable conditions for fibre-fermenting bacteria
- mucosal damage
Partial loss of rumen papillation

Fox (1938), Hofmann & Matern (1988)

- high proportion of fibre in diet
- loss of papillae in the dorsal rumen region
- rumen “like a cow”
‘Peracute mortality syndrome’


- sudden death
- related stress episode
- no discernable cause of death
- total absence/atrophy of body fat stores
‘Peracute mortality syndrome’

normal coronary fat

no coronary fat

(photos courtesy John Potter 2004)

‘Serous fat atrophy syndrome’

‘Chronic energy deficiency’
Ruminant feeding types (Hofmann)

from Hofmann (1989)
Ruminant feeding types (Hofmann)

from Hofmann (1989)
Don’t believe names, think for yourself

• What is a ‘concentrate selector’?

*EUROPE: RUMINANT FEEDING TYPES*

- **Concentrate selectors**
  - ibex
  - reindeer
  - roe deer
  - chamois
  - moose

- **Intermediate types**
  - red deer
  - goat
  - fallow

- **Grass/roughage eaters**
  - mouflon
  - sheep
  - cattle
  - aurox

*from Hofmann (1989)*
Do diets of grazers and browsers really differ?

<table>
<thead>
<tr>
<th>Species</th>
<th>Crude fiber (%) dry matter</th>
<th>NDF (%) dry matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giraffe (<em>Giraffa camelopardalis</em>)</td>
<td>-</td>
<td>50–70</td>
</tr>
<tr>
<td>Okapi (<em>Okapia johnstoni</em>)</td>
<td>-</td>
<td>43–48</td>
</tr>
<tr>
<td>Moose (<em>Alces alces</em>)</td>
<td>20–45</td>
<td>50–70</td>
</tr>
<tr>
<td>White-tailed deer (<em>Odocoileus virginianus</em>)</td>
<td>-</td>
<td>35–50</td>
</tr>
<tr>
<td>Buffalo (<em>Syncerus caffer</em>)</td>
<td>30–40</td>
<td>-</td>
</tr>
<tr>
<td>Waterbuck (<em>Kobus ellipsiprymnus</em>)</td>
<td>30–40</td>
<td>-</td>
</tr>
</tbody>
</table>

from Clauss & Dierenfeld (2008)
## Differences between grass and browse

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>5-15</td>
<td>1-5</td>
<td>1-2</td>
<td>15-40</td>
<td>20-40</td>
</tr>
<tr>
<td>Browse</td>
<td>5-15</td>
<td>-</td>
<td>6-12</td>
<td>8-12</td>
<td>12-30</td>
</tr>
</tbody>
</table>

From Robbins (1993)
Don‘t lose perspective!

a slow car?
an alcohol-free beverage?
a 'concentrate-selector?'

Don‘t lose perspective!
Crude fibre in rumen contents
(Drescher-Kaden & Seifelnasr 1977)

(\% dry matter)

20 %  
Area 1  
20 %

24 %  
Area 2  
34 %
Traditional feeding approach

1. “Browse contains more protein, more soluble cell content, and less fibre than grass”

2. “Concentrate selectors’ are adapted to a food high in rapidly fermenting carbohydrates”

=> “Browsers should receive more protein and less fibre than grazers”
Hay:concentrate ratio in different ruminant species in one zoo

Data from Grisham and Savage (1990)
# Diseases of the digestive tract

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<thead>
<tr>
<th>Feeding type</th>
<th>n</th>
<th>Diseases of the digestive tract (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazer</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Mixed feeder</td>
<td>141</td>
<td>31</td>
</tr>
<tr>
<td>Browser</td>
<td>61</td>
<td>26</td>
</tr>
</tbody>
</table>

Data from Kiupel (1988)
Rumen mucosa of moose

Finnish moose

captive moose (Whipsnade Zoo)

from Hofmann & Nygren (1992)
Changes in rumen mucosa indicating ruminen acidosis

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<tr>
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<td>13</td>
<td>23</td>
</tr>
<tr>
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<td>30</td>
<td>27</td>
</tr>
<tr>
<td>Browser</td>
<td>24</td>
<td>83</td>
</tr>
</tbody>
</table>

Data from Marholdt (1991)
The so-called ‘concentrate selectors’ seem to suffer from the ingestion of too much concentrates!
**Ad libitum intake of grass hay in zoo ruminants**

![Graph showing the relationship between body weight and OM intake for different categories of ruminants.](Image)

From Foose (1982)
The so-called ‘concentrate selectors’ seem to suffer from the ingestion of too much concentrates ...

... or too little hay!
Problems with hay acceptance


**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)
Scenario I:

Hay *ad libitum*

Concentrates

*ad libitum*
Scenario I:

Hay *ad libitum*

Concentrates *ad libitum*

*all ruminants ingest too much concentrates and develop rumen acidosis*
Scenario I:

Hay *ad libitum*

Concentrates *ad libitum*

During evolution, herbivores learned to select for energy-dense feeds which are rare in their natural environment.

*all* ruminants ingest too much concentrates and develop rumen acidosis
Scenario II:

Hay *ad libitum*

Concentrates *restrictive*
Scenario II:

- Hay *ad libitum*
- Concentrates *restrictive*

Grazers eat enough hay to suit their ruminant GIT physiology
Scenario II:

**Hay ad libitum**

**Concentrates restrictive**

Browsers often do not ingest enough hay to suit their ruminant GIT physiology
Scenario II:

Hay *ad libitum*

Concentrates restrictive

Browsers often do not ingest enough hay to suit their ruminant GIT physiology
Scenario II:

Hay *ad libitum*

Concentrates restrictive

Browsers often do not ingest enough hay to suit their ruminant GIT physiology

**why?**
Grazer

Grass → longish, “fibre-like” particles →
high reticular crests
large omasum

dorsal attachment
irregular papillation
thick rumen pillars
strong rumen muscle layers

Browser

Browse → polygonal particles →
low reticular crests
small omasum

mostly no attachment
even papillation
thin rumen pillars
weak rumen muscle layers
**Grazer**
- Irregular papillation
- Thick rumen pillars
- Strong rumen muscle layers
- High reticular crests
- Large omasum
- Dorsal attachment

**Browser**
- Mostly no attachment
- Even papillation
- Thin rumen pillars
- Weak rumen muscle layers
- Low reticular crests
- Small omasum
Fecal particle size in herbivores

- We expect captive herbivores to have finer faecal particles than free-ranging conspecifics (due to pellet feeding).
- This is confirmed in Aurochs but not in giraffes!
- Indication that giraffe teeth are adapted to chewing something else - not the diets offered in captivity.

![Graph showing MPS (mm) for free-ranging and captive Aurochs and Giraffe from Hummel et al. (2008)]
Fecal particle size in herbivores

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![Graph showing MPS (mm) for free-ranging and captive Aurochs and Giraffe](from Hummel et al. (2008))
Does it matter? Husbandry success

- Measured as average lifespan in relation to maximum lifespan (humans: $80/120 = 0.67$)
Husbandry success

- Browsing ruminants have lower relative lifespans than grazing ruminants

from Müller et al. (2011)
High proportion of concentrates

High proportion of hay fibre
High proportion of concentrates

High proportion of hay fibre

individual animal feeding decision/habit
(hay quality)
High proportion of concentrates

High proportion of hay fibre
High proportion of concentrates

High proportion of hay fibre

Chronic acidosis, hoof overgrowth, oral stereotypies
Hoof overgrowth / chronic laminitis

from Nocek (1997)
Photos: E. Flach, M. Claussi
Hoof overgrowth / chronic laminitis

from Nocek (1997)
Photo: W. Zenker
Hoof overgrowth - ‘anecdotes’

Giraffe survey: Zoos with hoof problems fed more fruits/bread/grains than zoos without such problems (Hummel et al. 2006).

Moose survey: Zoos with hoof problems fed more non-roughages (incl. fruits) than zoos without such problems (Clauss et al. 2002).

Comparing two wild ruminant herds, the one with a higher proportion of concentrates had a lower rumen pH and worse claws (Zenker et al. 2009).
High proportion of concentrates -> High proportion of hay fibre -> Chronic acidosis, hoof overgrowth, oral stereotypies
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High proportion of hay fibre → escape of large fibrous particles
High proportion of concentrates → High proportion of hay fibre → escape of large fibrous particles → bezoar formation → Chronic acidosis, hoof overgrowth, oral stereotypies
High proportion of concentrates

High proportion of hay fibre

Chronic acidosis, hoof overgrowth, oral stereotypies

Loss of dorsal rumen papillation

escape of large fibrous particles

bezoar formation
High proportion of concentrates → High proportion of hay fibre → Rumen "blockage" = low intake → Escape of large fibrous particles → Bezoar formation → Chronic acidosis, hoof overgrowth, oral stereotypies → Loss of dorsal rumen papillation
High proportion of concentrates

High proportion of hay fibre

Chronic acidosis, hoof overgrowth, oral stereotypies

Rumen "blockage" = low intake

No body fat stores, stress susceptibility

Loss of dorsal rumen papillation

Escape of large fibrous particles

Bezoar formation
Chronic acidosis, hoof overgrowth, oral stereotypies

You want a concentrate food that does this …

rumen “blockage” = low intake

… without inducing this.
What's in a commercial food?
What's in a commercial food?

Protein  17.5 %
What's in a commercial food?

Protein 17.5%
Crude fibre 8.5%
What's in a commercial food?

Protein  17.5 %
Crude fibre  8.5 %
Crude ash  10.0 %
### What's in a commercial food?

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
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<td>Protein</td>
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</tr>
<tr>
<td>Crude fibre</td>
<td>8.5 %</td>
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<tr>
<td>Crude ash</td>
<td>10.0 %</td>
</tr>
<tr>
<td>Crude fat</td>
<td>2.5 %</td>
</tr>
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Protein 17.5%
Crude fibre 8.5%
Crude ash 10.0%
Crude fat 2.5%
Moisture 10.0%
What's in a commercial food?

Protein: 17.5%
Crude fibre: 8.5%
Crude ash: 10.0%
Crude fat: 2.5%
Moisture: 10.0%
Total: 48.5%
What's in a commercial food?

Protein 17.5 %
Crude fibre 8.5 %
Crude ash 10.0 %
Crude fat 2.5 %
Moisture 10.0 %
Total 48.5 %

What are the other 51.5 %?
What's in a commercial food?

Protein  17.5 %
Crude fibre  8.5 %
Crude ash  10.0 %
Crude fat  2.5 %

Moisture  10.0 %

Total  48.5 %

What are the other 51.5 %?

“Starch & Sugar” / “Soluble fibre”
Choosing a pelleted diet

![Graph showing the relationship between Crude protein (% dry matter) and Soluble carbohydrates (% dry matter) with data points for Grass/Lucerne and Browse.]
Choosing a pelleted diet
Choosing a pelleted diet

![Diagram showing the relationship between crude protein and soluble carbohydrates for different diets: Grass/Lucerne, Browse, Domestic pellets, and Game pellets. The x-axis represents crude protein (% dry matter), while the y-axis represents soluble carbohydrates (% dry matter). The data points are color-coded for each diet type.](image-url)
Choosing a pelleted diet

Crude protein (% dry matter)

Soluble carbohydrates (% dry matter)

- Grass/Lucerne
- Browse
- Domestic pellets
- Game pellets
- 3 brands
Choosing a pelleted diet

- Grass/Lucerne
- Browse
- Domestic pellets
- Game pellets
- 3 brands

Crude protein (% dry matter)

Soluble carbohydrates (% dry matter)
Choosing a pelleted diet

Crude protein (% dry matter)

Soluble carbohydrates (% dry matter)

- Grass/Lucerne
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Choosing a pelleted diet

- Crude fibre (% dry matter)
- Soluble carbohydrates (% dry matter)

- Grass/Lucerne
- Browse
Choosing a pelleted diet

- Grass/Lucerne
- Browse
- Domestic pellets
Choosing a pelleted diet

- Grass/Lucerne
- Browse
- Domestic pellets
- Game pellets
Choosing a pelleted diet

Diagram showing the relationship between crude fibre and soluble carbohydrates for different types of pelleted diets. The diagram includes data for Grass/Lucerne, Browse, Domestic pellets, Game pellets, and 3 brands, with each category represented by different colored markers.
Choosing a pelleted diet

- Grass/Lucerne
- Browse
- Domestic pellets
- Game pellets
- 3 brands

Crude fibre (% dry matter)

Soluble carbohydrates (% dry matter)

- SDS Moose (Cellulose Pulver)
- Purina Moose (Sägemehl)
- Boskos (Bush)
and if browsers don’t eat enough hay ...

<table>
<thead>
<tr>
<th>Brand name</th>
<th>Crude fibre (% DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbivore 16-ADF&lt;sup&gt;1&lt;/sup&gt;</td>
<td>16.7</td>
</tr>
<tr>
<td>Herbivore 25-ADF&lt;sup&gt;1&lt;/sup&gt;</td>
<td>25.6</td>
</tr>
<tr>
<td>Browser breeder&lt;sup&gt;1&lt;/sup&gt;</td>
<td>27.8</td>
</tr>
<tr>
<td>Browser maintenance&lt;sup&gt;1&lt;/sup&gt;</td>
<td>31.1</td>
</tr>
<tr>
<td>Moose maintenance&lt;sup&gt;1&lt;/sup&gt;</td>
<td>35.6</td>
</tr>
<tr>
<td>Grazer&lt;sup&gt;2&lt;/sup&gt;</td>
<td>11.2</td>
</tr>
<tr>
<td>Browser breeder&lt;sup&gt;2&lt;/sup&gt;</td>
<td>18.6</td>
</tr>
<tr>
<td>Browser maintenance&lt;sup&gt;2&lt;/sup&gt;</td>
<td>21.4</td>
</tr>
<tr>
<td>Moose&lt;sup&gt;2&lt;/sup&gt;</td>
<td>24.0</td>
</tr>
</tbody>
</table>

1 Mazuri<sup>®</sup> (PMI, St. Louis, USA)
2 Mazuri<sup>™</sup> (SDS, Essex, UK)

from Clauss & Dierenfeld (2008)
Chronic acidosis, hoof overgrowth, oral stereotypies

rumen “blockage” = low intake

You want a rougaghe that does not do this.
This represents app. 1.5 kg edible browse per 5 animals.
Daily amount of browse for one okapi (on a browse-only diet)
(courtesy J. Hummel)
How do you know you feed enough browse?

1 hour after browse feeding:
### Forages for grazers

<table>
<thead>
<tr>
<th>Grass hay</th>
<th>Lucerne hay</th>
<th>Browse</th>
</tr>
</thead>
<tbody>
<tr>
<td>For large Bovines hay of low feeding quality (not hygienic quality) acceptable; meet increased requirements (e.g. lactation) using hay of higher nutritional value</td>
<td>Not necessary</td>
<td>Not necessary</td>
</tr>
</tbody>
</table>

Additionally fresh green forage/silage
## Forages for browsers

<table>
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<tr>
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<th>Lucerne hay</th>
<th>Browse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is usually not accepted readily; high quality (mixed meadow, clover/herbs) can be adequate</td>
<td>Best option; if high quality it allows selection of leafy parts</td>
<td>As much as available; ensile for winter</td>
</tr>
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Additionally fresh green forage/silage
Offering a variety of roughages (NOT fruits/concentrates) may be favourable for browsers - it allows selection among non-harmful substances; in other words: this is when they can use the nutritional wisdom they evolved in evolution!

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Extreme browsers (like moose) are best kept if browse is available constantly from zoo-run plantations or from forests nearby.
What is she dreaming of?
What is she dreaming of?