Camel Nutrition & Feeding

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Part 1. Basic Nutrition

- Nutrient Requirements
Outline

✓ Nutrient Requirements
  ✓ Energy, *maintenance and milk*
  ✓ Protein, *maintenance*
  ✓ Vitamin E and Selenium, *for normal function*
  ✓ Feed additives, *ionophores*
  ✓ Recommendations
Demand for energy

- **Maintenance**, energy required for:
  - essential muscular activity (*beating of the heart & respiration*)
  - active transport (*movement against the concentration gradient*)
  - synthesis of essential body constituents like enzymes and hormones.

In a starved animal, energy for these processes comes from catabolism of body reserves (glycogen, fat, protein)

**Energy used for maintenance is converted to heat**

In a fasting animal: heat produced = energy derived from catabolism

- **Production**

  New tissue primarily as protein, fat, products of conception (foetus and placenta), milk, egg, wool,
Gross energy (GE) (Heat of combustion)

- Faecal energy
- Digestible energy (DE)
  - Metabolisable energy (ME)
    - Urinary energy
    - Methane energy
  - Energy used for maintenance (Em)
  - Energy stored (E_g) or Secreted (E_l)

Net energy (NE)

- Heat increment (HI)

Total heat production of the animal
Metabolizable Energy Requirements for Maintenance (MEm)

Based on net energy requirement \( E_m = 0.396 \text{ MJ/kg}^{0.73} \) (MAFF, 1975)
Daily Maintenance Allowance of ME for Dairy Cattle (MEI, MJ/day)

R² = 0.9994

Dairy Cattle 300 – 600 kg

MEm allowance (MJ of ME per day)

Body weight (kg)

Daily Maintenance **Allowance** of ME for Dairy Cattle (MEI, MJ/day)
Metabolizable Energy Requirements for Maintenance (MEm)

Camels 300 – 600 kg BW

Based on $Em = 0.314 \text{ MJ/kg}^{0.75}$ (Guerouali & Wardeh 1998)
Daily Maintenance **Allowance** of ME for Camels (MEm, MJ/day)

Camels 300 – 600 kg BW

\[ R^2 = 0.9994 \]
Metabolizable Energy Requirements for Maintenance (MEm) per Metabolic Body Weight (kg^{0.75})
Metabolizable Energy Requirements for Maintenance (ME\textsubscript{m}) per Metabolic Body Weight (kg\textsuperscript{0.73})
Daily MEm Allowances

MEm allowances (MJ per day)

Body weight (kg)

Camels
Cattle

Daily MEm Allowances

Al Jassim 2017
Metabolizable Energy Requirements for Milk

**Information needed:**

\( EV_I \): the energy value of milk

\( Y \): milk yield

\( K_I \): the efficiency of utilization of Metabolizable Energy for milk production = 0.62

\( ME_I \): Metabolizable energy for milk = \( EV_I / 0.62 \), which with the inclusion of 0.05 safety margin becomes:

\[
ME_I = 1.694 \ EV_I \ \text{MJ/kg milk}
\]
Example:

<table>
<thead>
<tr>
<th></th>
<th>SNF (g/kg)</th>
<th>BF (g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report 1</td>
<td>95.9</td>
<td>37.8</td>
</tr>
<tr>
<td>Report 2</td>
<td>99.2</td>
<td>30.8</td>
</tr>
<tr>
<td>Report 3</td>
<td>101</td>
<td>29.0</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>98.7</strong></td>
<td><strong>32.5</strong></td>
</tr>
</tbody>
</table>

\[ EV_I = 0.0386 \times BF + 0.0205 \times SNF - 0.236 \]

\( EV_I \) is the energy value of milk secreted in MJ/kg

\( SNF \) is the solid non fat in g/kg

\( BF \) is the butter fat in g/kg

\[ EV_I = 0.0386 \times 32.5 + 0.0205 \times 98.7 - 0.236 = 3.042 \]

The ME requirements for milk = 1.694 \( EV_I \) MJ/kg milk

\[ MEI = 1.694 (0.0386 \times 32.5 + 0.0205 \times 98.7 - 0.236) = 5.15 \text{ MJ/Kg} \]

Thus a 450 kg camel producing 10 kg milk requires \sim 92 \text{ MJ of ME per day}
### Metabolizable energy requirements for camel milk with different fat and SNF contents

<table>
<thead>
<tr>
<th>Fat%</th>
<th>SNF%</th>
<th>EV₁</th>
<th>MJ of ME per kg Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>10.295</td>
<td>2.840</td>
<td>4.810</td>
</tr>
<tr>
<td>3</td>
<td>10.013</td>
<td>2.975</td>
<td>5.040</td>
</tr>
<tr>
<td>3.5</td>
<td>9.731</td>
<td>3.110</td>
<td>5.270</td>
</tr>
<tr>
<td>4</td>
<td>9.449</td>
<td>3.245</td>
<td>5.500</td>
</tr>
<tr>
<td>4.5</td>
<td>9.168</td>
<td>3.380</td>
<td>5.720</td>
</tr>
<tr>
<td>5</td>
<td>8.886</td>
<td>3.516</td>
<td>5.950</td>
</tr>
</tbody>
</table>

Al Jassim, 2017
ME requirements per kg of milk with different fat%
Protein Requirements
Nitrogen Metabolism

Feed

Protein

Undegradable

Degradable

NPN

NPN: Non-protein Nitrogenous Compounds

Salivary Glands

Liver

Kidney

NH$_3$

Urea

Urine

Small Intestine

Diet

Forestomach

Liver
Nitrogen Metabolism

Diet

Feed

Protein

NPN: Non-protein Nitrogenous Compounds

NPN

Undegradable

Degradable

Peptides

Amino Acids

Ammonia (NH$_3$)

Microbial Protein

Salivary Glands

Urea

Liver

Kidney

Urine

Small Intestine
## Nitrogen Balance Data

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake</td>
<td>825 mg/kg\textsuperscript{0.75}</td>
</tr>
<tr>
<td>Faecal</td>
<td>301 mg/kg\textsuperscript{0.75}</td>
</tr>
<tr>
<td>Urinary</td>
<td>400 mg/kg\textsuperscript{0.75}</td>
</tr>
</tbody>
</table>

**Balance:**

- **Total** 123 mg/kg\textsuperscript{0.75}
- % of intake 14.9
- % of digested 23.5

## Protein Requirement for Maintenance:

- 349 mg digestible nitrogen (DN) per kg\textsuperscript{0.75} .......(1)
- Allowance: 368 mg of DN per kg\textsuperscript{0.75} ............(2)

*Adapted from Farid (1995)*
# Maintenance protein requirements for camels

<table>
<thead>
<tr>
<th>BW</th>
<th>g DN</th>
<th>g DCP</th>
<th>g CP/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>32.9</td>
<td>206</td>
<td>321</td>
</tr>
<tr>
<td>450</td>
<td>36.0</td>
<td>225</td>
<td>351</td>
</tr>
<tr>
<td>500</td>
<td>38.9</td>
<td>243</td>
<td>380</td>
</tr>
<tr>
<td>550</td>
<td>41.8</td>
<td>261</td>
<td>408</td>
</tr>
</tbody>
</table>

Adapted from Farid (1995)
Daily requirements for crude protein (CP), calcium (Ca) and phosphorous (P) per kg of milk with different fat% adapted from NRC, 1989 on Dairy Cows

<table>
<thead>
<tr>
<th>Fat %</th>
<th>Total CP (g)</th>
<th>Ca (g)</th>
<th>P (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>78</td>
<td>2.73</td>
<td>1.68</td>
</tr>
<tr>
<td>3.5</td>
<td>84</td>
<td>2.97</td>
<td>1.83</td>
</tr>
<tr>
<td>4.0</td>
<td>90</td>
<td>3.21</td>
<td>1.98</td>
</tr>
<tr>
<td>4.5</td>
<td>96</td>
<td>3.45</td>
<td>2.13</td>
</tr>
<tr>
<td>5.0</td>
<td>101</td>
<td>3.69</td>
<td>2.28</td>
</tr>
<tr>
<td>5.5</td>
<td>107</td>
<td>3.93</td>
<td>2.43</td>
</tr>
</tbody>
</table>

Adapted from NRC, 1989 on Dairy Cows
Vitamin E & Selenium
Changes in the plasma Vit E concentration.


Treatments: T1, 240 IU of Vit E; T2, 480 IU of Vit E; T3, 720 IU of Vit E.
Supplementation stopped
Supplementation started

Pre-treatment Period | Treatment Period | Post-treatment Period

Treatments: T1, 1.6 mg Se; T2, 3.2 mg Se; T3, 4.8 mg Se.

Changes in the plasma Se concentration

Unpublished date: Malo, Skidmore, Al Jassim (2017: unpublished data)
A proposed routes of Se in the camel

A: rapid loss of Se
B: slow loss of Se

Diet + Supplement

Muscle

Faeces
Unabsorbed dietary & endogenous

Liver

Kidney

Urine

Al Jassim, (2017: Unpublished)
Camel-E + RPC
Vitamin E & Se plus Rumen Protected Choline (RPC)
**Role of choline**

**Adipose tissue**

- Triacylglycerol (TAG)
- Lipolysis
- Nonesterified fatty acids (NEFA)
- Glycerol

**Liver**

- Ketone bodies
- NEFA → Acetyl CoA
- CO₂
- TAG

**Mobilization of fat**

**Negative energy balance (NEB) & hormonal changes in late pregnancy**

**Very low density lipoprotein (VLDL)**

*Shahsavari, D’Occhio, Al Jassim 2015*
Part 2. Applied Nutrition and nutritional problems of the intensively managed camels
Protein Sources

- SBM
- Corn gluten meal
- CSM
- PKM
- Canola meal
- Sunflower meal
A standard Urea-Molasses- Multinutrient Block (UMMB)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molasses</td>
<td>30 – 50</td>
</tr>
<tr>
<td>Urea</td>
<td>5 – 10</td>
</tr>
<tr>
<td>Cereal Bran</td>
<td>15 – 25</td>
</tr>
<tr>
<td>Oil seed meal</td>
<td>10 – 20</td>
</tr>
<tr>
<td>Salt</td>
<td>5 – 7</td>
</tr>
<tr>
<td>Lime or cement</td>
<td>5 – 10</td>
</tr>
<tr>
<td>Bone meal</td>
<td>5 – 7</td>
</tr>
<tr>
<td>Minerals</td>
<td>1 - 2</td>
</tr>
</tbody>
</table>

Source: IAEA (http://www-naweb.iaea.org/nafa/aph/faq-ummb.pdf)
Some aspect of urea nutrition: prevent urea toxicity

- Adding urease inhibitors into the rumen
- Inducing urease immunity & decreasing ureolytic activity in the rumen
- Coating urea with resistant materials
Protein

NPN: Non-protein Nitrogenous Compounds

Peptides
Amino Acids
Microbial Protein

Diet

NPN: Non-protein Nitrogenous Compounds

CHO

Peptides

Amino Acids

Microbial Protein

NH₃
NH₄⁺
H⁺

NH₄⁺
NH₃
H⁺

NH₃
H⁺

NH₃
H⁺

NH₃
H⁺

NH₃
H⁺

NH₃
H⁺

NH₃
H⁺

NH₄⁺

NH₃

NH₃

NH₃

NH₃

NH₄⁺

NH₃

NH₃

NH₃

Blood

pH 7.3-7.4

Nitrogen Metabolism

Small Intestine

Diet

Forestomach

CHO

VFAs

NH₃ + H⁺ → NH₄⁺
Diet → Protein → NPN → NPN: Non-protein Nitrogenous Compounds

NPN: Non-protein Nitrogenous Compounds

CHO → VFAs

VFAs → H⁺ → NH₃ + H⁺ → NH₄⁺

NPN: Non-protein Nitrogenous Compounds

NH₄⁺ → NH₃ → pH 7.3-7.4

Blood

Nitrogen Metabolism → Small Intestine
Alternative H and C pathways for reducing ruminal methanogenesis

Plant material

H + CO₂ → Methane

Methanogens

2-12% of GE of feed

H + CO₂ → Acetate

Acetogens

Gases produced

☺ VFAs ☺

H + CO₂ → Acetate

2-12% of GE of feed
The contrasting processes of methanogenesis & acetogenesis

Methanogenesis:

\[ \text{CH}_4 + 3\text{H}_2\text{O} \rightarrow \Delta G^{0'} = -136 \text{ kJ/mol} \]

Acetogenesis:

\[ \text{CH}_3\text{COO}^- + 3\text{H}_2\text{O} \rightarrow \Delta G^{0'} = -105 \text{ kJ/mol} \]
Acidosis
Low pH
The predominant bacterial species in the camel’s foregut

Ghali et al. 2011
Cellulolytic Bacteria

*Streptococcus bovis*

*Lactobacillus* spp.

Cellulolytic Bacteria
Streptococcus bovis
Lactobacillus spp.

Milinovich et al. 2007. Environ Microbiol: 9(8), 2090–2100
4 hours

Cellulolytic Bacteria

*Streptococcus bovis*

*Lactobacillus spp.*

Milinovich et al. 2007. *Environ Microbiol*: 9(8), 2090–2100
Cellulolytic Bacteria

Streptococcus bovis

Lactobacillus spp.

Milinovich et al. 2007. Environ Microbiol: 9(8), 2090–2100
Streptococcus bovis

Selenomonas ruminantium

Lactobacillus vitulinus

Lactate

pH
Selenomonas ruminantium L14
Lactic acid utilising bacteria

The bacterial isolates % of added lactic acid utilised

Selenomonas ruminantium L14

> 90%

The bacterial isolates

Lactate utilising bacteria
Figure 1.
Grain sources categorized by rate of ruminal fermentation.
Adapted from Stock and Britton (1993).

- Faster
  - Dry-rolled wheat
  - Steam-rolled barley
  - Dry-rolled barley
  - Temper-rolled barley
  - Whole barley
  - High-moisture corn (bunker), flaked wheat
  - Steam-flaked corn
  - Steam-flaked sorghum
  - High-moisture corn (stored whole)
  - Dry-rolled corn, reconstituted sorghum
- Slower
  - Dry-rolled sorghum

Fermentation of grains in the compartmental stomach
Relationship between lactic acid and total acid production from *in vitro* fermentation of grain

\[ y = 0.78x - 28.1 \]

\[ r^2 = 0.95 \]

Source: Bird *et al.*, 1999
In vitro fermentation and enzyme digestibility of starch in cereal grain

<table>
<thead>
<tr>
<th>Grain</th>
<th>Cultivar</th>
<th>Starch digestibility (% of original)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fermentation</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>Mean</td>
</tr>
<tr>
<td>Barley</td>
<td>20</td>
<td>67</td>
</tr>
<tr>
<td>Wheat</td>
<td>7</td>
<td>48</td>
</tr>
<tr>
<td>Oat</td>
<td>4</td>
<td>72</td>
</tr>
<tr>
<td>Sorghum</td>
<td>20</td>
<td>44</td>
</tr>
<tr>
<td>Triticale</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>Maize</td>
<td>1</td>
<td>42</td>
</tr>
</tbody>
</table>

(Bird et al., 1999)
Starch content and pH of faeces collected from steers fed barley and sorghum diets

<table>
<thead>
<tr>
<th>Grain</th>
<th>Faeces</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Starch %</td>
<td>pH</td>
<td></td>
</tr>
<tr>
<td>Dry-Rolled Sorghum</td>
<td>25</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Dry-Rolled Barley</td>
<td>4</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td>Steam-Flaked Sorghum</td>
<td>2</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>Steam-Flaked Barley</td>
<td>2</td>
<td>6.2</td>
<td></td>
</tr>
</tbody>
</table>

Source: Watts & Tucker, 1993
Co-Grazing cattle and Camels

Important:
Do not treat your camels like cattle
Total and individual VFAs & *in vitro* dry matter digestibility (IVDMD) of Mitchell grass

<table>
<thead>
<tr>
<th>VFA (mmol/L)</th>
<th>Cattle Co-grazed with camels</th>
<th>Cattle grazed alone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>20 (0 h) 4.0 (48 h)</td>
<td>20 (0 h) 24.0 (48 h)</td>
</tr>
<tr>
<td>Propionic</td>
<td>9.0 (0 h) 3.6 (48 h)</td>
<td>9.2 (0 h) 8.4 (48 h)</td>
</tr>
<tr>
<td>n-Butyric</td>
<td>4.7 (0 h) 25.8 (48 h)</td>
<td>4.88 (0 h) 6.9 (48 h)</td>
</tr>
<tr>
<td>Total</td>
<td>38.0 (0 h) 36.9 (48 h)</td>
<td>39.0 (0 h) 43.5 (48 h)</td>
</tr>
<tr>
<td>IVDMD% (48 h)</td>
<td>36.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Monensin Toxicosis in camels fed a commercial beef cattle concentrate mix. Torticollis, irreversible position of the neck before death of 13 month old camel (Al Jassim et al. 2016)
Increase pericardial fluid in 13 month old camel

Diaphragm (A); caudal vena cava (B); phrenic nerve (C); cranial vena cava (D); pericardial fluid (E).

(Al Jassim et al. 2016)
Severe oedema in a camel exposed to four-week monensin toxicity with large amount of clear peritoneal fluid inside the abdominal cavity. (Al Jassim et al. 2016)
Mycotoxins

Source:
Aspergillus flavus,
A. parasiticus,
A. ochraceus, and
Fusarium graminearum

Toxins:
Ochratoxin A
Aflatoxin
Zearalenone

Caused the death of more than 6000 camels in Riyadh region in Saudi Arabia in 2007
Tapeworms in camels, Southeast Queensland
Thank you