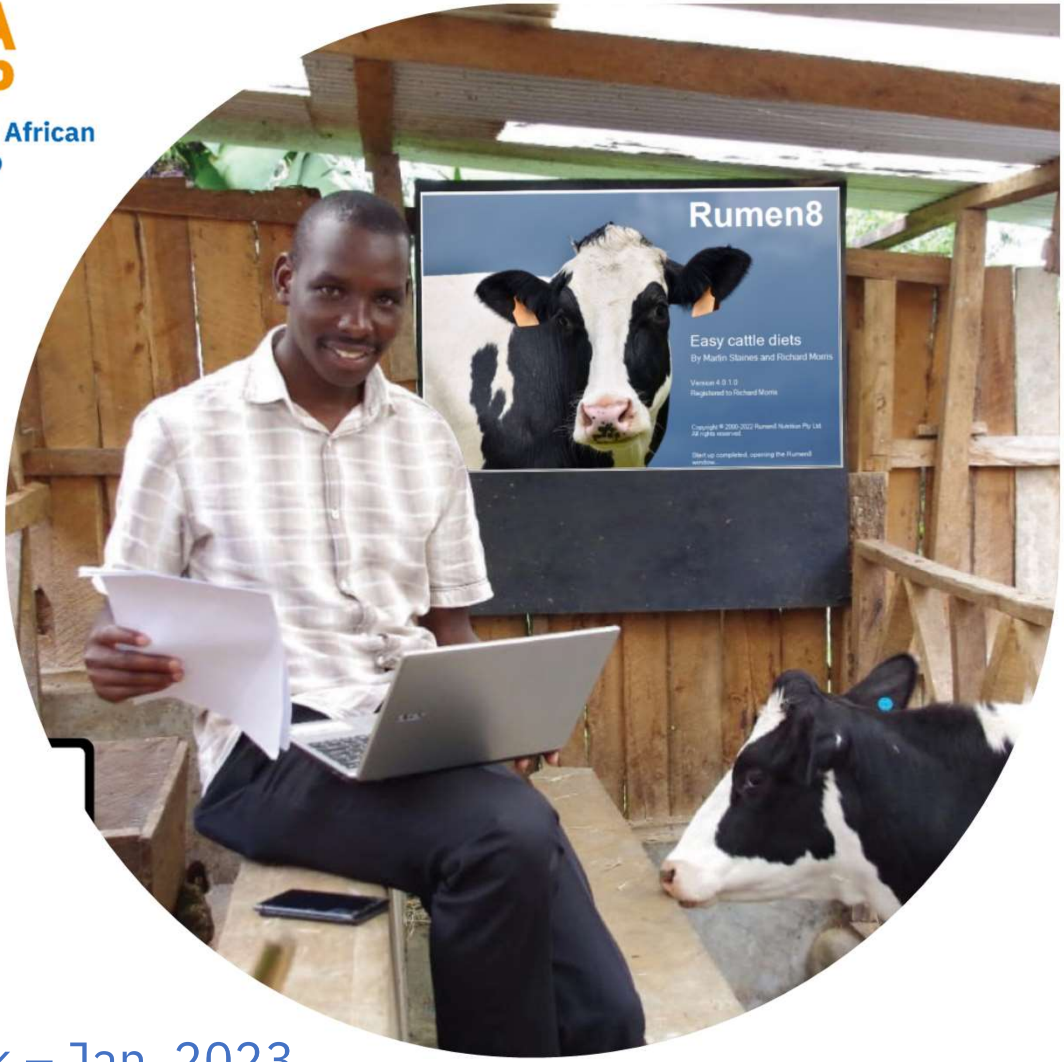
Dairy cattle nutrition in the tropics using Rumen8

PART 1: Understanding ruminant nutrition



By M. Staines, J. Creemers and H. Perdok – Jan. 2023

Part 1A Introduction

NEA DAP
Netherlands East African Dairy Partnership

Acknowledgements

- This course has been made possible by funding from the Netherlands East Africa Dairy Partnership
- This course has been created by Rumen8 Nutrition Pty Ltd, with expert input from ProDairy East Africa Ltd and 'PUM Netherlands Senior Experts' with experience in East Africa
- Information presented in parts ONE & TWO of this course is based in part on material developed by Dairy Australia
- East Africa photo credits: Jos Creemers, Hink Perdok, Martin Staines, Victor Otieno, Tseard van der Kooi, Nieke Westerik and Imre van der Kolk and SNV

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Course Goal

To improve knowledge and skills of trainees so that they can confidently use the Rumen8 software application to make informed on-farm nutrition decisions to improve farm profit.

Objectives Parts ONE & TWO

- Understand how the rumen works and problems that may occur
- Understand nutrition terminology
- Understand cow requirements in relation to performance
- Understand the nutrients provided by different feeds
- Ability to use tools for feed & water budgeting

Objectives Parts THREE to SIX

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- Understand how Rumen8 works (Parts 3 & 4)
- Understand how to apply Rumen8 in the field to improve farm profitability (Parts 5 & 6)

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Agenda

PART ONE

- Feeding into its context
- Ruminants digestion
- Common nutrition terms
- What is in feeds?
- Cow requirements

PART TWO

- Feeding heifers
- Feed characteristics
- Factors affecting intake
- Balancing a diet
- Cost effective feeding
- Feed planning

Q & A Discussion

Part 1B
Context

East African dairy systems are diverse

System	Description
A	Predominantly based on grazing
B	Mixed system (pasture and supplements)
C	Zero grazing system (full cut and carry)

Feeding and nutrition influence income & expenses & thus profit

=

-

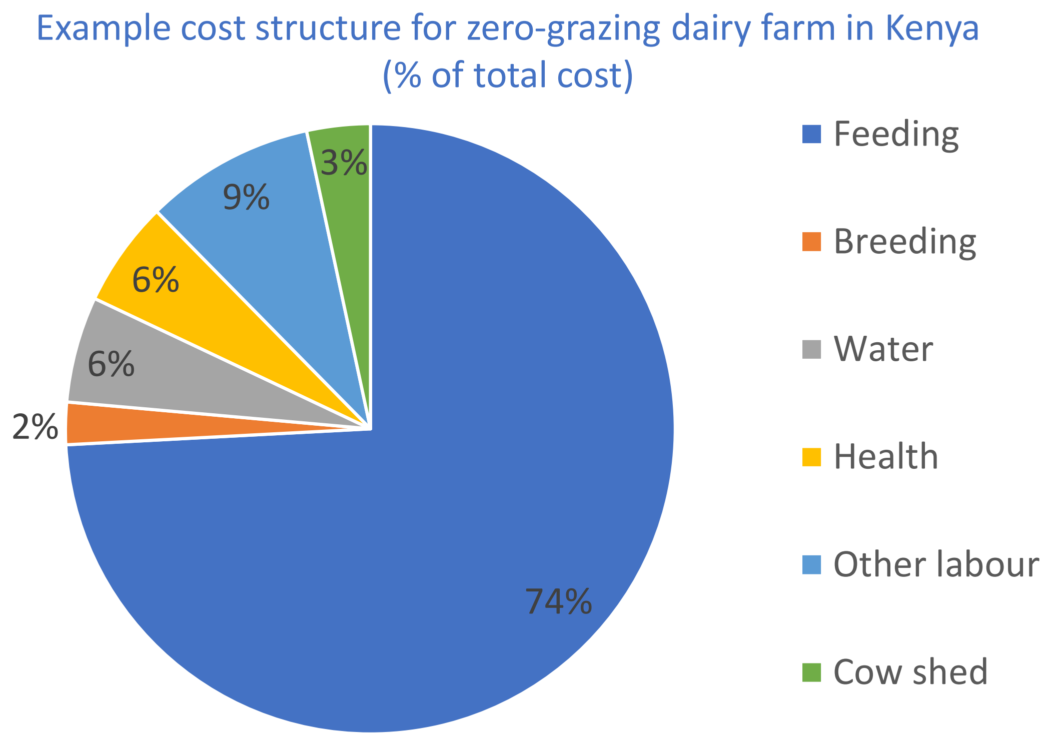
Improved feeding increases income

- Milk income increases through improved
  - milk volume
  - milk quality & composition
- Livestock income increases through improved
  - herd fertility
  - herd health

Improved feeding improves return on expenses

- Feed costs represent about 60-75% of total cost of production, depending on the production system

- Profit can often be improved by improved nutrition, better feed purchasing decisions, and reduced wastage



Feeding and nutrition in context

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- Regardless of which dairy system is followed, informed feeding decisions are essential if dairy farms are to be profitable and sustainable

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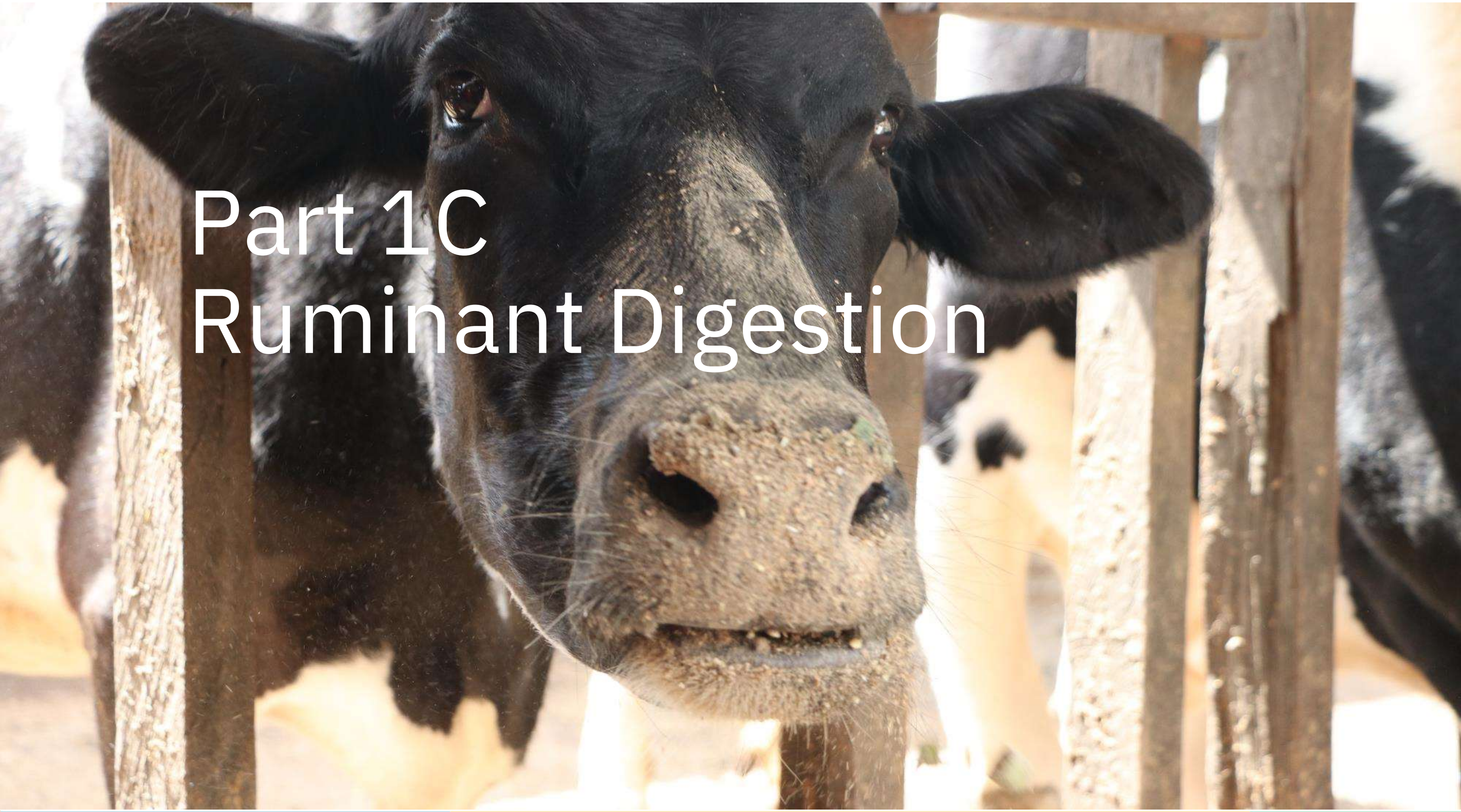
Q & A
Discussion

Part 1C
Ruminant Digestion



Cows are ruminants

Ruminant

From Wikipedia, the free encyclopedia
(Redirected from Ruminants)

Ruminants (suborder **Ruminantia**) are hoofed herbivorous grazing or browsing mammals that are able to acquire nutrients from plant-based food by fermenting it in a specialized stomach prior to digestion, principally through microbial actions. The process, which takes place in the front part of the digestive system and therefore is called foregut fermentation, typically requires the fermented ingesta (known as cud) to be regurgitated and chewed again. The process of rechewing the cud to further break down plant matter and stimulate digestion is called **rumination**.[2][3] The word "ruminant" comes from the Latin *ruminare*, which means "to chew over again".

The ruminant digestive tract

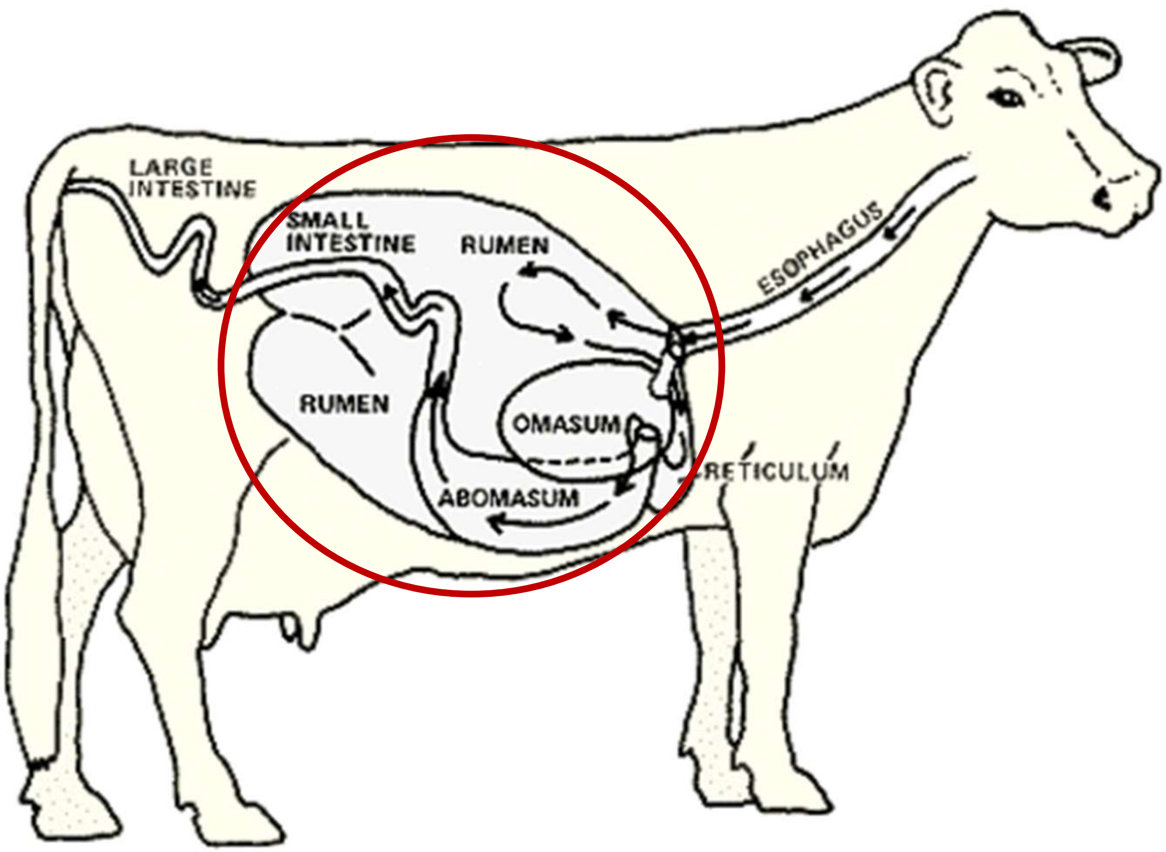
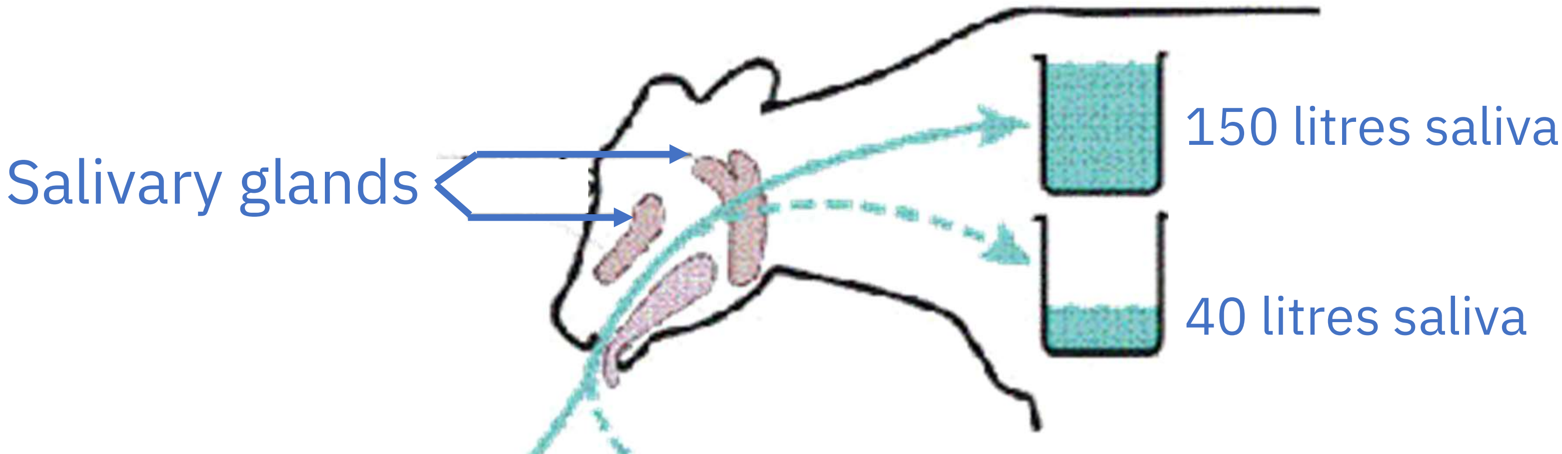


Image: https://extension.umn.edu/dairy-nutrition/ruminant-digestive-system

The mouth

- No upper incisors – replaced by dental pad
- Tongue rolls around grass
- Tongue, incisors, and dental pad tear off forage
- Molars grind feed down
- Saliva lubricates & buffers feed

Chewing is important

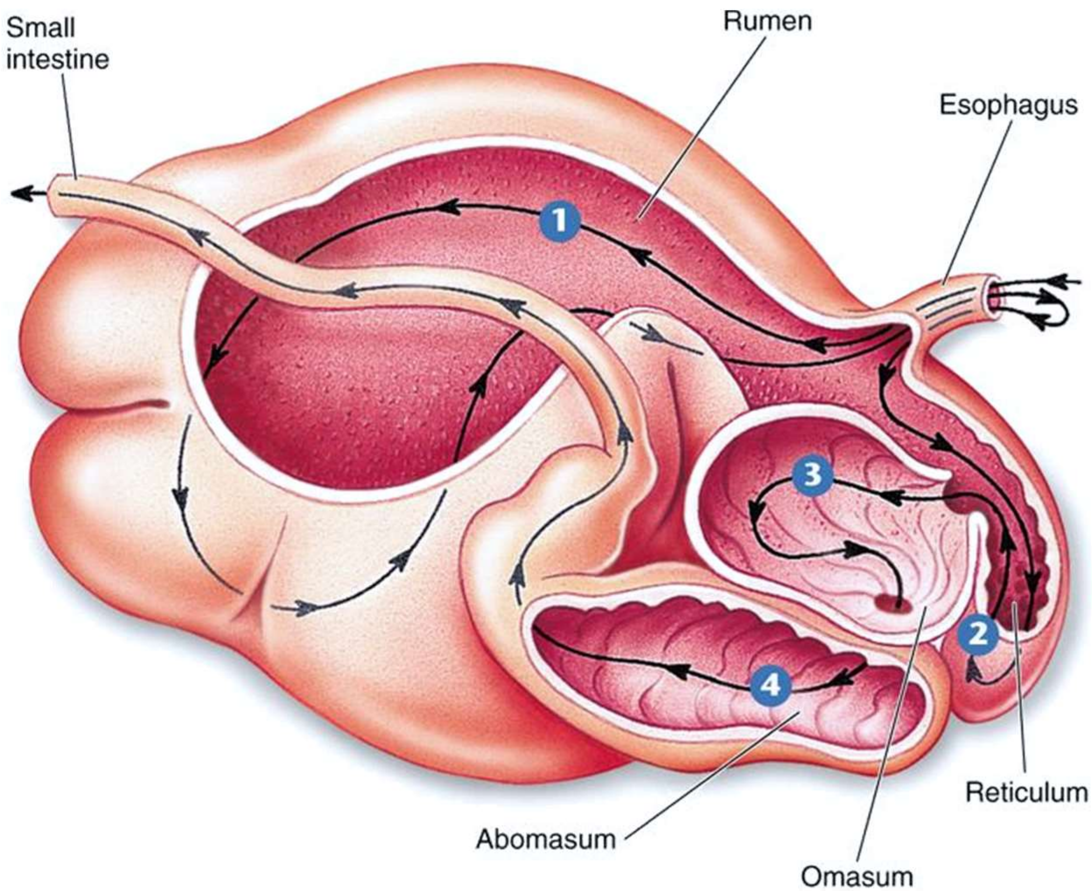


Roughage

Concentrate

Image: http://www.milkproduction.com/Library/Scientific-articles/Animal-health/Digestive-Physiology-of-the-Cow/

Chambers of the ruminant stomach



Left image: http://www.zo.utexas.edu/faculty/sjasper/images/f31.15.jpg
Right image: Feeding Dairy Cows 5th Edition

The reticulum

- Flask shaped first chamber of the "pre stomachs"
- Honeycomb appearance
- Sends undigested feed to rumen and fine particles to the omasum
- Long fibre scratching the reticulum wall stimulates regurgitation of feed during rumination; i.e. chewing cud
- Foreign objects often found here (hardware disease)

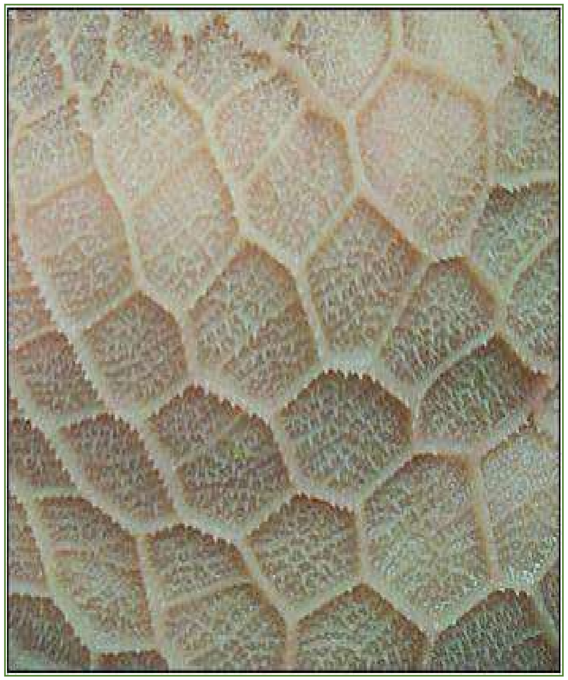


Image: http://www.vivo.colostate.edu/hbooks/pathphys/digestion/herbivores/rumen_anat.html

The rumen

- Large fermentation chamber (100-200 litres)
- Contains millions of microorganisms - bacteria, protozoa and fungi
- Lined with finger-like projections called papillae which absorb some of the products of digestion
- The rumen is the reason ruminants can utilise fibrous feeds

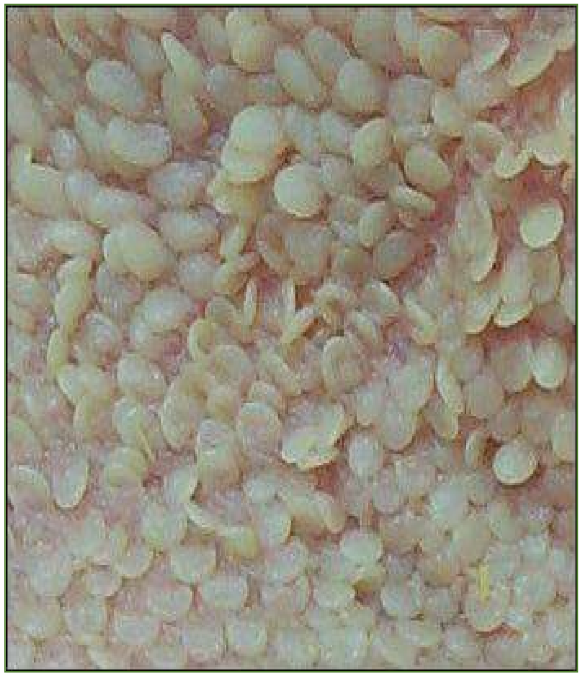


Image: http://www.vivo.colostate.edu/hbooks/pathphys/digestion/herbivores/rumen_anat.html

Rumen papillae

- Papillae increase the surface area of the rumen available for absorption
- The number and size of papillae increase when high energy diets are fed
- It takes 3 – 6 weeks for papillae to adapt to changes in diet

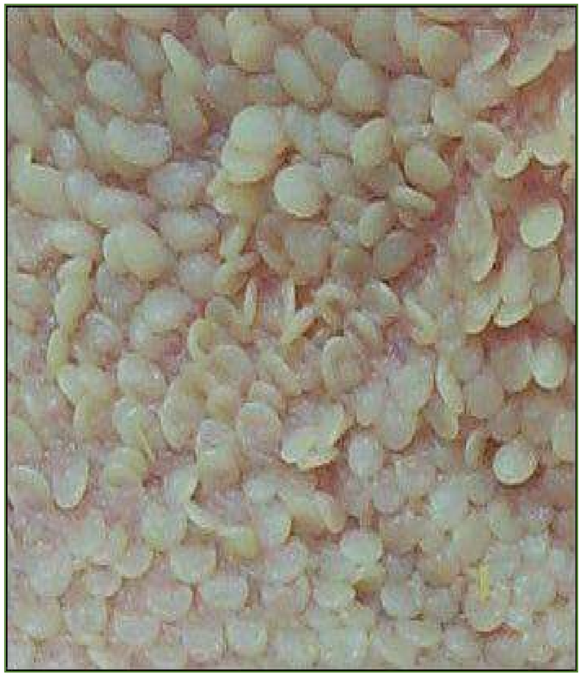
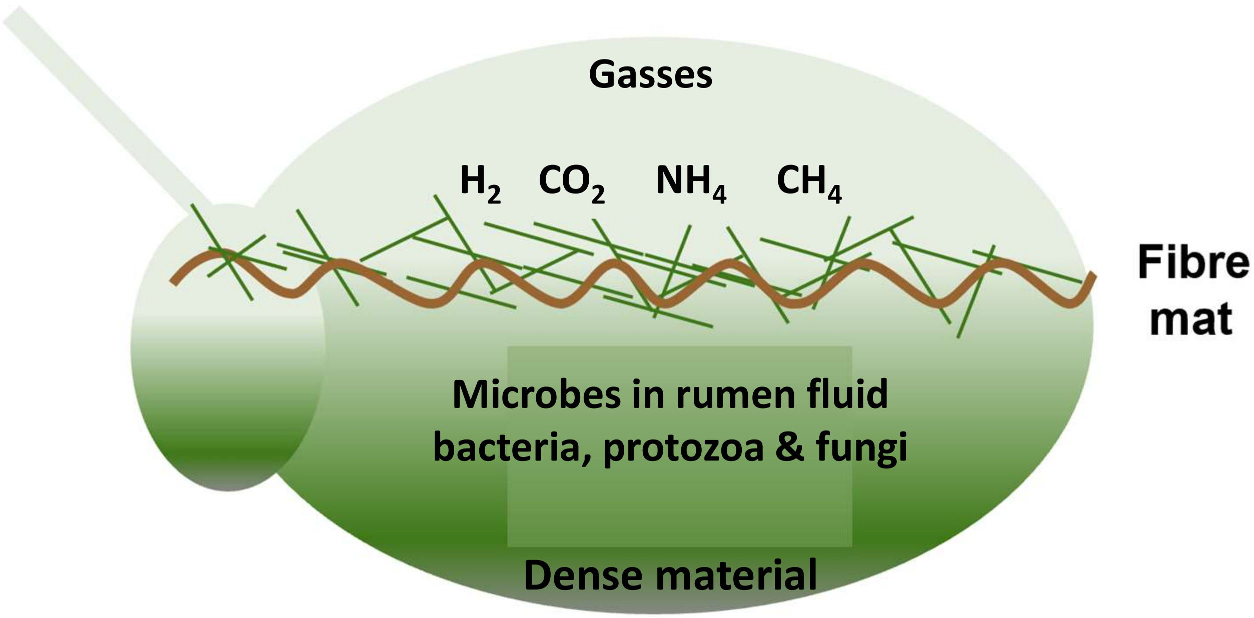


Image: http://www.vivo.colostate.edu/hbooks/pathphys/digestion/herbivores/rumen_anat.html

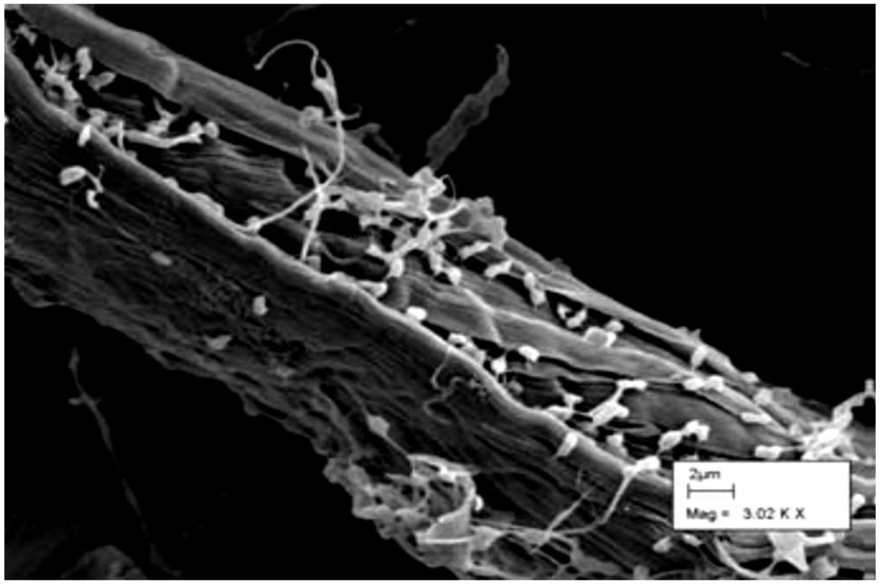
Rumen microbes

- Different rumen microbes breakdown different feedstuffs
- Two basic groups
  - **Fibre digesters** – do not survive pH less than 6
  - **Sugar / starch digesters** – tolerate lower pH than fibre digesters
- Population size of different microbes depends on diet
  - high fibre diet = more fibre digesters
  - high energy diet = more sugar / starch digesters
- Takes 7–10 days for microbe population to readjust when diet changes.

Inside the reticulo - rumen



Rumen microbes at work (under microscope)



Bacteria breaking down fibre

Photo Lydia Joubert

Images:https://microbewiki.kenyon.edu/index.php/Bovine_Rumen

Protozoa with attached fungi and bacteria *©1995, Mel Yokoyama & Mario A. Cobos*

Microbial fermentation in the rumen

- Microbes breakdown 70 – 80% of digestible organic matter in the rumen
- Microbial fermentation produces
  - more microbes
  - carbon dioxide (CO_2) & Hydrogen (H_2)
    (which react to form Methane [CH_4])
  - volatile fatty acids (VFAs)
    particularly Acetate, Propionate & Butyrate
    Energy dense: 15 21 & 25 MJ/kg

Microbial fermentation feeds the cow

- Volatile fatty acids absorbed across the rumen wall are the main source of **energy** for the cow
- Microbes flushed out of the rumen are digested and become the main source of **protein** for the cow

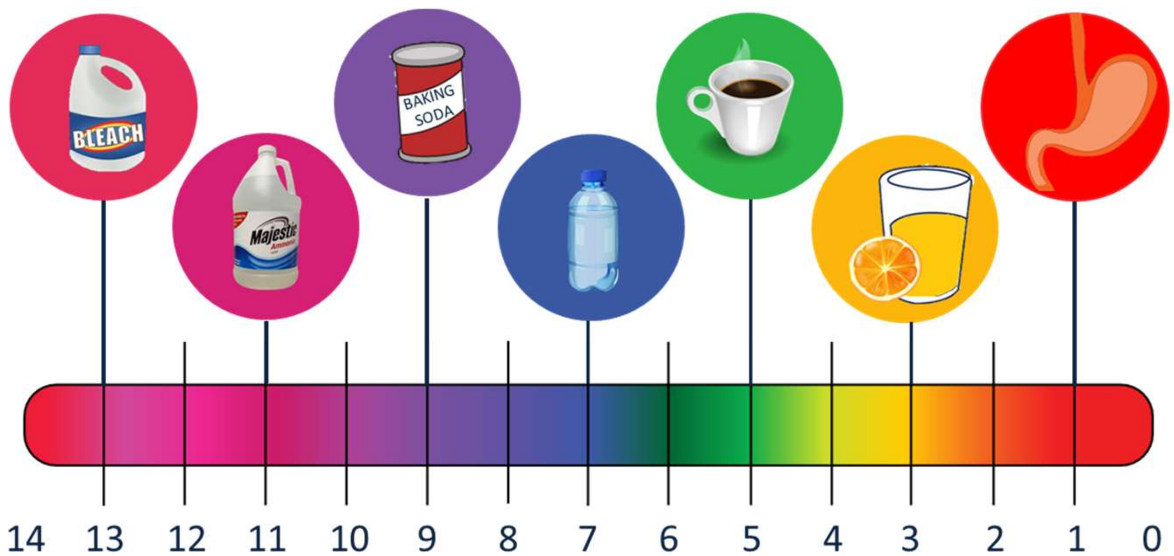
- MORE MICROBES = MORE MILK

Maintaining a healthy microbe population

- Rumen microbes require a stable environment
  - A balance of energy and protein in the diet
  - A consistent pH range between 6 – 7
  - Feed that is ground and mixed
  - Warm, moist, anaerobic (oxygen free) conditions

- Microbes do **NOT** like rapid change

pH Scale



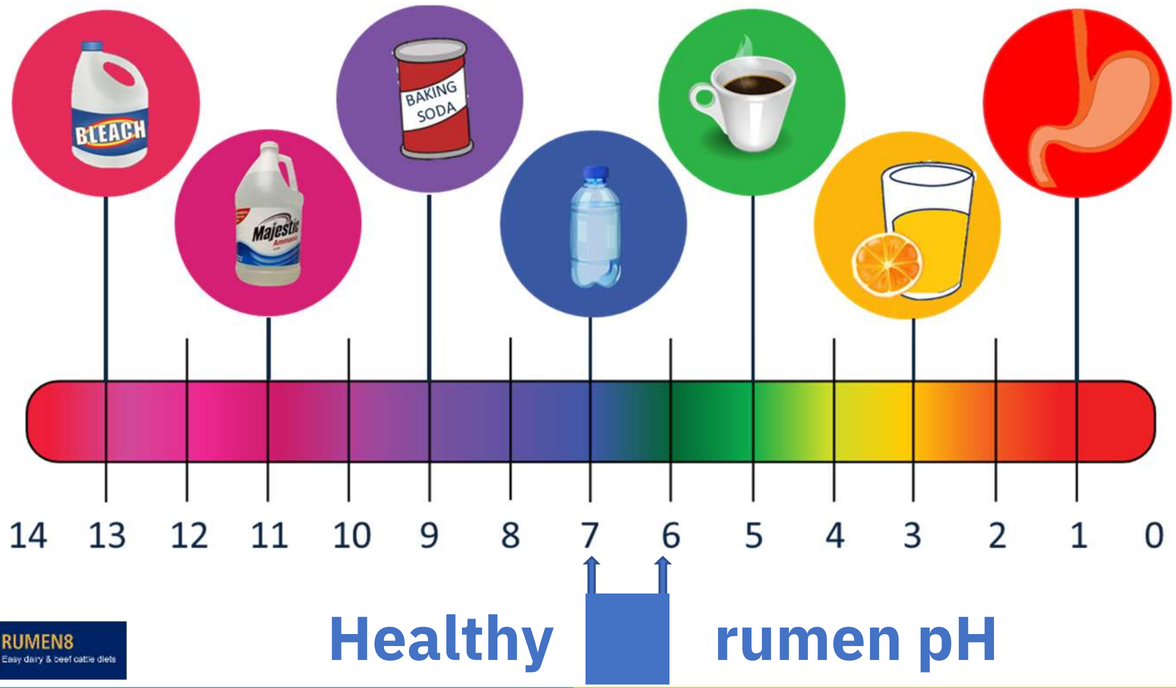
pH	H conc vs pure water
0	10,000,000
1	1,000,000
2	100,000
3	10,000
4	1,000
5	100
6	10
7	1
8	0.1
9	0.01
10	0.001
11	0.0001
12	0.00001
13	0.000001
14	0.0000001

pH in the reticulo – rumen

- A stable pH between 6 – 7 is ideal for most rumen microbes
  - Fibre digesting microbes do not survive at lower (more acidic) pH
  - A low pH (<5.5) may also cause damage to the rumen wall

- pH is maintained through
  - regular addition of buffers in the form of saliva which is produced in response to chewing long fibre
  - removal of VFAs produced during microbial digestion by absorption across the rumen wall

Healthy rumen pH – a narrow range!



Rumen pH – a quick guide	
Healthy	6.2 - 7.0
Ok	6.1 - 5.8
Risky	5.6 - 5.7
Lethal	5.5 or less

Signs of good rumen health

- Good appetite
- Rumination
  - Cows spend 35 – 40% of their day ruminating (8-10 hours). The majority of the herd should be ruminating when lying down. If not, they may not be getting enough long fibre in their diet
    - Each bolus should be chewed 55-70 times
    - The rumen should contract 10-12 times in 5 minutes
- Manure
  - Manure the consistency of porridge, containing few large particles and little undigested grain. Not too dry (too much fibre), not too loose (not enough fibre)

Perfect porridge poo!

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What can go wrong - Rumen Acidosis

- Rumen Acidosis
  - A build up of acid in the rumen
  - A decline in rumen pH below 5.6
- Causes:
  - Not enough long fibre in the diet to stimulate salivation and buffering of pH in the rumen
  - Too much rapidly digested sugar and starch in the diet producing VFAs faster than they can be removed from the rumen

Examining rumen papillae

- Healthy rumen on the left with good papillae
- Acidosis damaged rumen wall on the right

Acidosis Damage

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The omasum

- Sometimes called the 'many-plies' or 'book'
- Further grinding of the feed occurs here, via the tissue leaves (laminae)
- The main function is the removal of excess water prior to digesta entering the abomasum

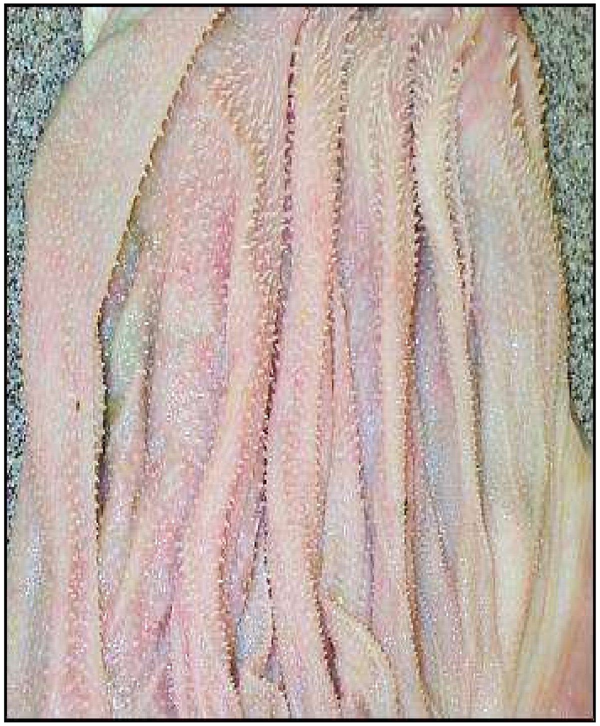

Image: http://www.vivo.colostate.edu/hbooks/pathphys/digestion/herbivores/rumen_anat.html

The abomasum

- The true stomach
- Secretion of gastric juices which aid in digestion
- Low pH (2.0-2.5) which immediately kills bacteria that have spilled over from the rumen
- Protein digestion occurs here

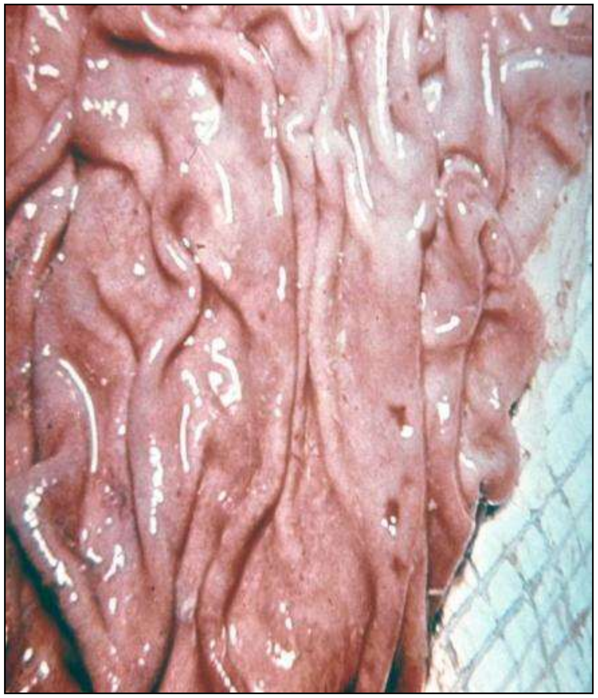

Image: http://www.vivo.colostate.edu/hbooks/pathphys/digestion/herbivores/rumen_anat.html

The intestines

- Small intestine
  - Continued digestion of feeds and microbes
  - Absorption of nutrients
- Large intestine
  - A further opportunity for microbial digestion (hindgut fermentation in the caecum)
  - Absorption of water and some nutrients

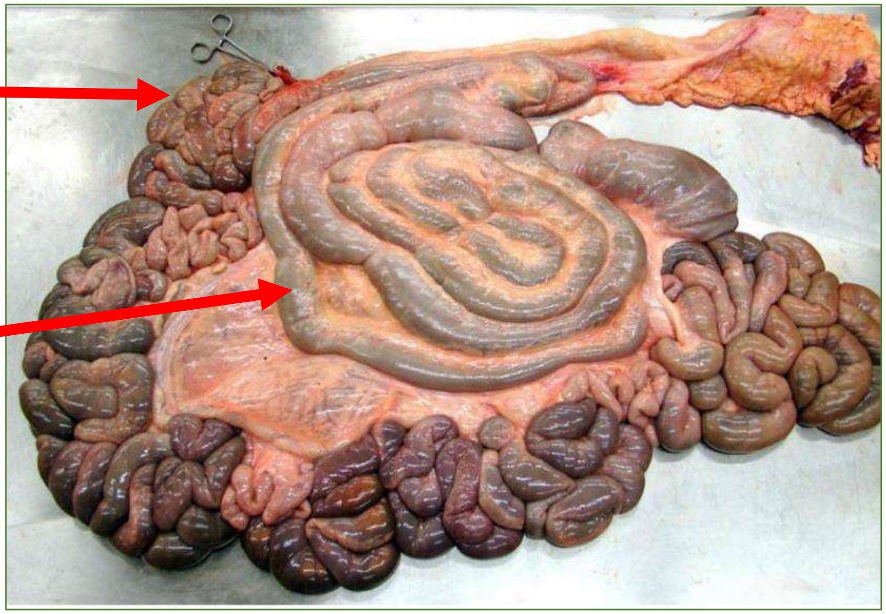

Image: http://vanat.cvm.umn.edu/ungDissect/Lab14/Img14-11.html

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Videos on the ruminant GI Tract

https://youtu.be/SVNNJf_28KE

https://youtu.be/oh9-U8DGV-U

https://youtu.be/E7I7qsZpgUs

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Key messages

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- Cows are ruminants. They chew their cud and have a four chambered stomach which has evolved to digest high fibre feeds
- Microbial digestion in the rumen supplies most of the cow's energy and protein needs
- Maintaining a large population of microbes in the rumen is the key to successful feeding of ruminants
- Microbes need a stable rumen environment and a balance of energy and protein to grow and reproduce
- Microbes don't like changes so make dietary changes gradually
- Long fibre is essential for maintaining rumen health


Q & A
Discussion

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Part 1D
What is in feeds?

Dry matter and digestibility

Feed “as fed” and Dry Matter

=

Dry Matter

+

Even Kenyan wildlife rangers talk about feed dry matter!

Feed dry matter content

- The proportion of the feed that remains after all the water has been removed
- Measured in grams per kg or as a percent (%)

Feed	DM g/kg	DM%
Banana pseudostem	100	10%
Fresh pasture	150-250	15-25%
Wet brewers grain	250	25%
Maize silage	300-350	30-35%
Molasses	750	75%
Rhodes grass hay	860	86%
Maize grain	890	89%
Brewers grain dry	900	90%
Soyabean meal	900	90%

Why do we care about dry matter?

- All the **energy & nutrients** in a feed are contained in the **dry matter** component
- We must compare the nutritional value of feeds on a dry matter basis
- We compare the cost of feeds on a dry matter basis
- To develop a balanced diet for cows we must know the content of dry matter, energy and nutrients of different feeds

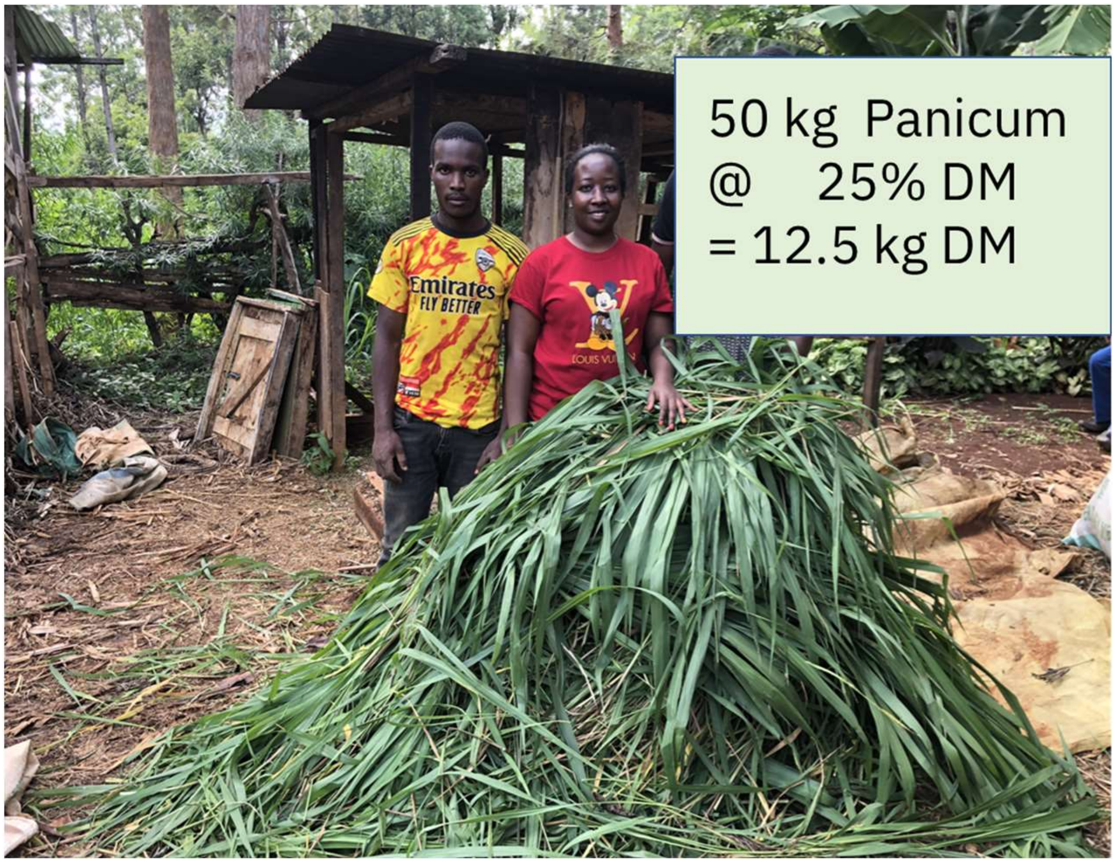
Concentrates typically contain 85%-95% dry matter (850-950 g/kg DM)

1 tonne maize grain ‘as fed’

890 kg dry matter

110 kg water

Fodder crops contain only about 25% DM



50 kg Panicum
@ 25% DM
= 12.5 kg DM

=

12.5 kg DM

37.5 kg water

How to determine DM content of a feed

- Collect a representative feed sample
  - Important and not always easy especially not for forages
- Weigh sample as soon as possible
  - Avoid any loss of moisture between collection and weighing
- Spread sample out on a flat tray or transfer sample into a large paper bag
- Carefully place the sample in a fan-forced drying oven at 60-70 ℃
- Dry for 48-72 hours
- Remove sample from oven and weigh as soon as sample has cooled down (normally within a few minutes)
- If sample was in a paper bag, weigh sample without paper bag
- Be careful not to spill any sample at any stage

How to calculate DM content of a feed

We need:

- The fresh weight of the feed (as fed)
- Dry the sample till all moisture fully removed and weigh again.
- Divide the dry weight by the fresh weight and multiply by 1000 (g/kg) *(or multiply by 100 for %)*

$$\textbf{Dry matter g/kg} = \frac{\textbf{Dry weight (g)}}{\textbf{Fresh weight (g)}} \textbf{ X 1000}$$

How much dry matter in 1 tonne of feed

Type of feed	Dry matter g/kg	Dry matter in 1 tonne ‘as fed’ (kg/1000 kg)	Kg ‘as fed’ per kg DM
Citrus pulp	190		
Kikuyu pasture	200		
Sorghum	230		
Maize silage	340		
Vetch silage	440		
Rhodes grass hay	850		
Sorghum grain	880		
Wheat straw	900		

How much dry matter in 1 tonne of feed

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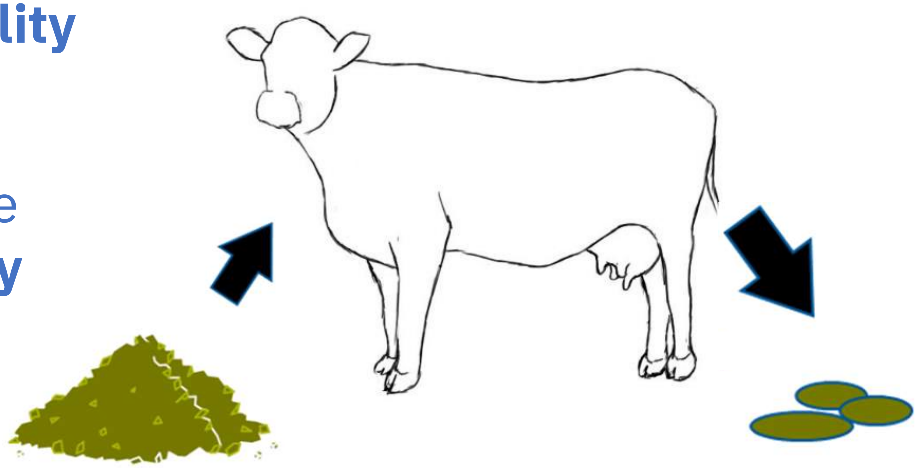
Type of feed	Dry matter g/kg	Dry matter in 1 tonne ‘as fed’ (kg/1000 kg)	Kg ‘as fed’ per kg DM
Citrus pulp	190	190	5.3
Kikuyu pasture	200	200	5.0
Sorghum	230	230	4.3
Maize silage	340	340	2.9
Vetch silage	440	440	2.3
Rhodes grass hay	850	850	1.2
Sorghum grain	880	880	1.1
Wheat straw	900	900	1.1

Dry matter digestibility (DMD%)

- The proportion of feed dry matter that is actually digested by the animal. Typically expressed as a %

- 10 kg DM eaten with 3 kg DM in manure
  = 7 kg DM digested = **70% digestibility**

- 10kg DM eaten with 5.5 kg DM in manure
  = 4.5 kg DM digested = **45% digestibility**



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Digestibility and feed quality

- The more digestible a feed, the more nutrients can be extracted from it by the animal
- High quality feed is highly digestible

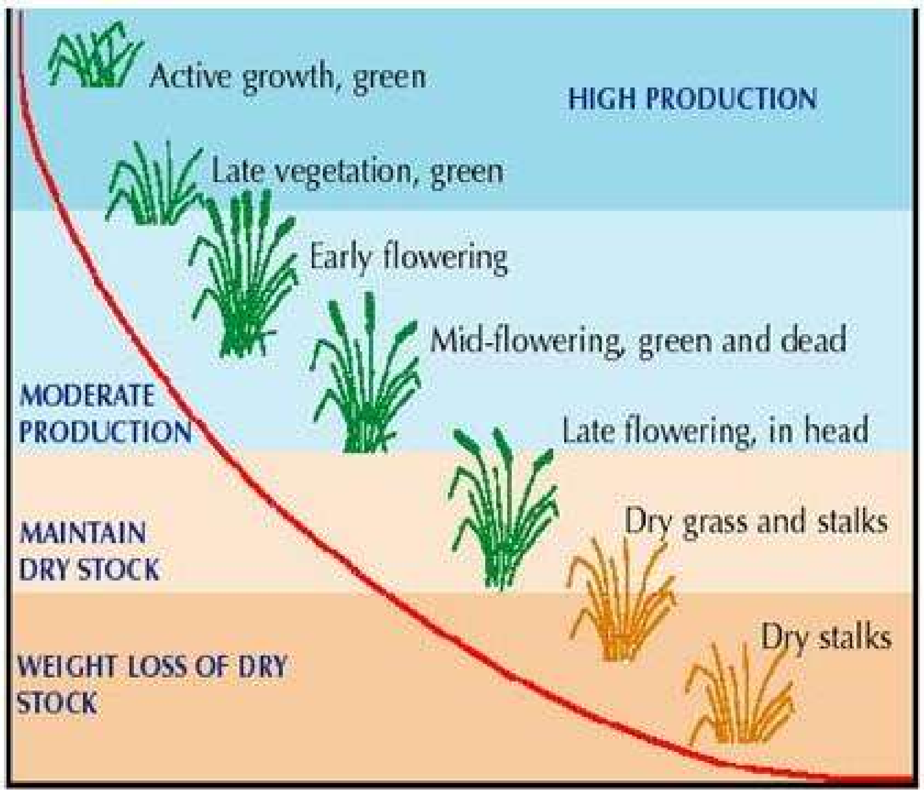
Factors affecting digestibility

- Species
  - Legumes are more digestible than grasses at the same stage of maturity (e.g. Lucerne vs African Foxtail grass)
- Management & Maturity
  - Vegetative grasses are more digestible than grasses that are reproductive (i.e. with seed heads)
- Processing
  - Grinding, rolling, cracking and other forms of grain processing can increase digestibility

Impact of stage of grass maturity on DM digestibility and energy content

Digestibility% ME MJ/kg DM

70 10



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Time

Pasture growth stage	DMD%	ME (MJ/kg DM)
Early, rapid vegetative growth	70	10.0
Beginning to grow stem, mostly green	60	8.2
Flowering and seed set, growth slows, 10-30% green	55	7.4
Senescence, no growth, no green	50	6.5

https://futurebeef.com.au/resources/energy-supplements/

Pasture management is key

- Good feed quality is essential in dairy cow nutrition
  - To maximise energy and nutrient content per kg
  - To maximise feed DM intake
- For this reason make sure to harvest tropical grasses in the early vegetative stage when they are at their best quality

What’s in feed dry matter?

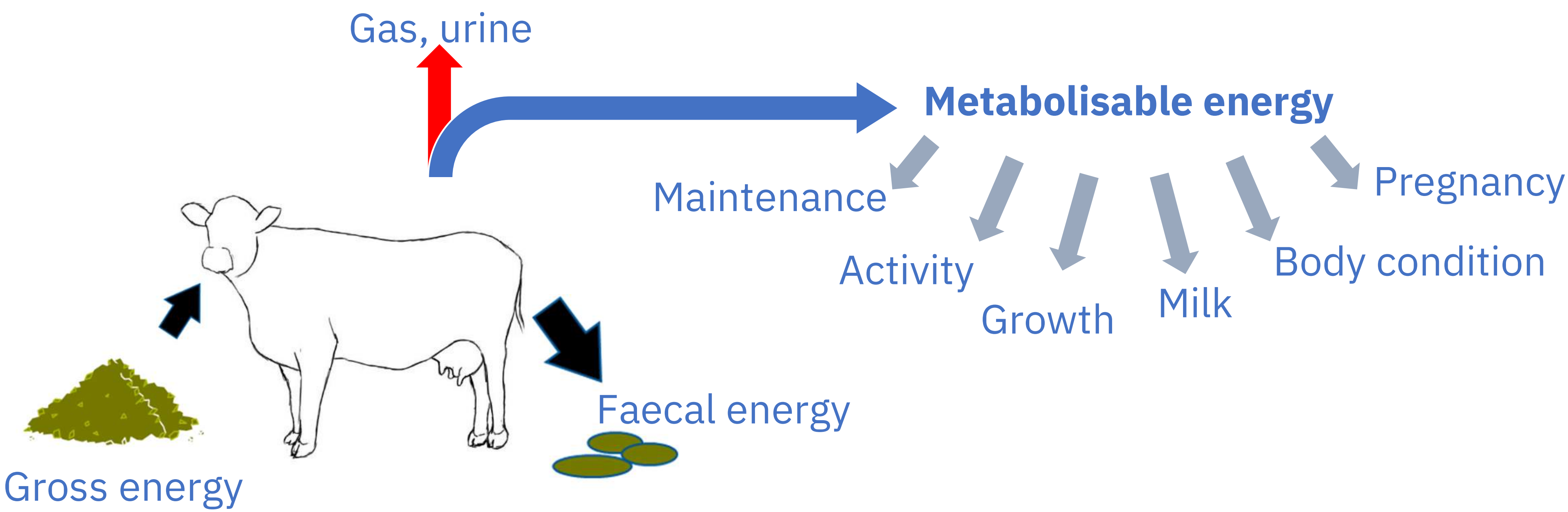
- Energy
- Protein
- Fibre
- Minerals
- Vitamins

Energy

Energy

- The measure of a feed's ability to support the 'work of life'
- Is needed for
  - maintenance
    (breathing, blood circulation, digestion and all other bodily processes)
  - physical activity (standing, walking etc.)
  - production of milk and meat etc.
  - pregnancy
  - storage of body reserves (body fat)

Metabolisable Energy (ME)
= energy in a feed that a cow can use



Use of Metabolisable Energy generates heat

- Use of ME for maintenance and production generates heat, so only part of the ME is retained in animal product
- The energy that is retained from ME is called **Net Energy (NE)**
- Typical efficiencies of use of ME (so-*called 'k-value'*) are:
  - Maintenance ~70%
  - Lactation ~60%
  - Growth 40-50%
  - Pregnancy 10-15%

- The *k-value* varies with the ME density of feeds.
  Feeds with a higher ME density are used more efficiently.

How do we express metabolisable energy?

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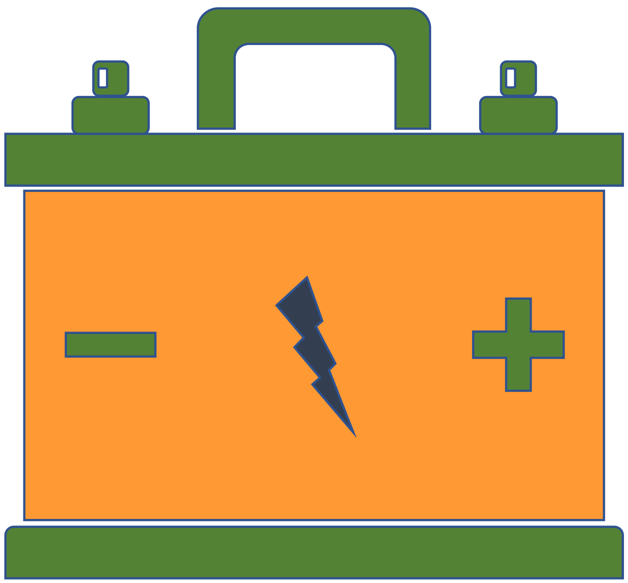
- ME is expressed in Megajoules (**MJ**)
- Feed is described as having “X” **MJ ME/kg DM**
- A cow needs approx. **100 to 200 MJ ME** per day depending on her size and level of production
- An adult human male needs about 9-10 MJ/day



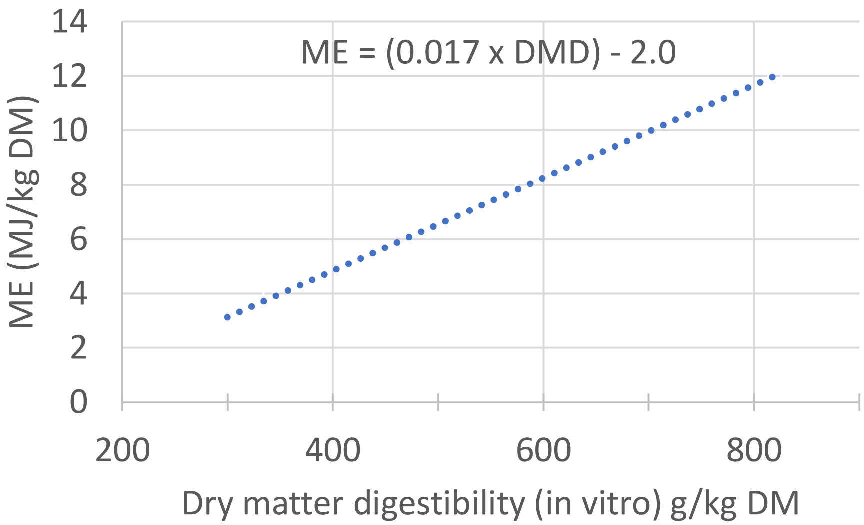
MJ

How ME is measured in feed analysis labs

- Various lab methods have been developed to estimate feed ME from 'in vitro digestibility'
  - Digestibility measured 'in a test tube' using digestive enzymes (1960's)
  - Nowadays feed ME (and other nutritional measures) is estimated using sophisticated 'near-infrared (NIR) spectroscopy' scanners
  - Requirement for reliable NIR 'calibration data' can limit accuracy of NIR

- Example equations to estimate ME from in vitro digestibility (g/kg DM)
  - ME = (0.017 * dry matter digestibility) - 2.0
  - ME = (0.016 * organic matter digestibility) – 1.8
  - ME = (0.018 * dry matter digestibility) – 1.8

(SCA 1990 Feeding standards for Australian livestock - Ruminants)



Typical ME densities of diets for dairy cows at different stages of lactation

Animal	MJ ME required per kg DMI
Dry cow empty (0 LWC)	8.3
Dry cow pregnant 8 months	9.0
Cow early lactation 10 litres (-0.5 LWC)	9.2
Cow early lactation 20 litres (-0.5 LWC)	10.3
Cow early lactation 30 litres (-0.5 LWC)	10.8
Cow late lactation 10 litres (+0.6 LWC)	10.2
Cow late lactation 20 litres (+0.6 LWC)	11.0

Typical ME values of various classes of feeds

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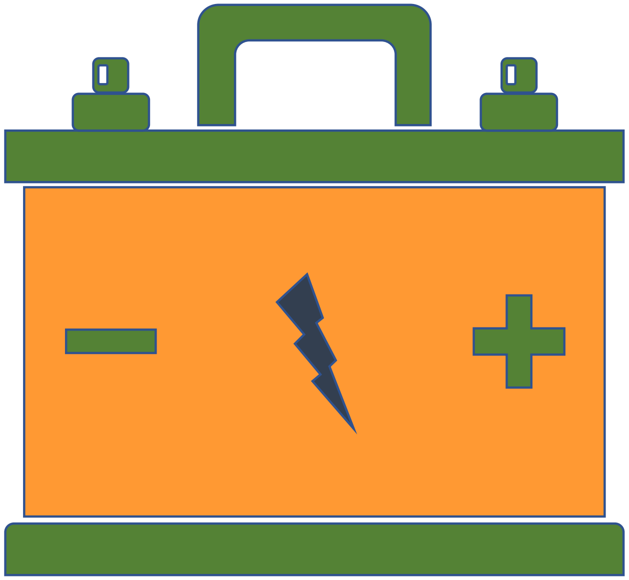
Feed	ME in MJ/kg DM
Poor quality fibrous forages	5-7
Medium quality forages	8-9
Good quality forages	10-11
Compound feeds	11-12
Cereal grains	12-13
Protein meals with some fat/oil	13-14

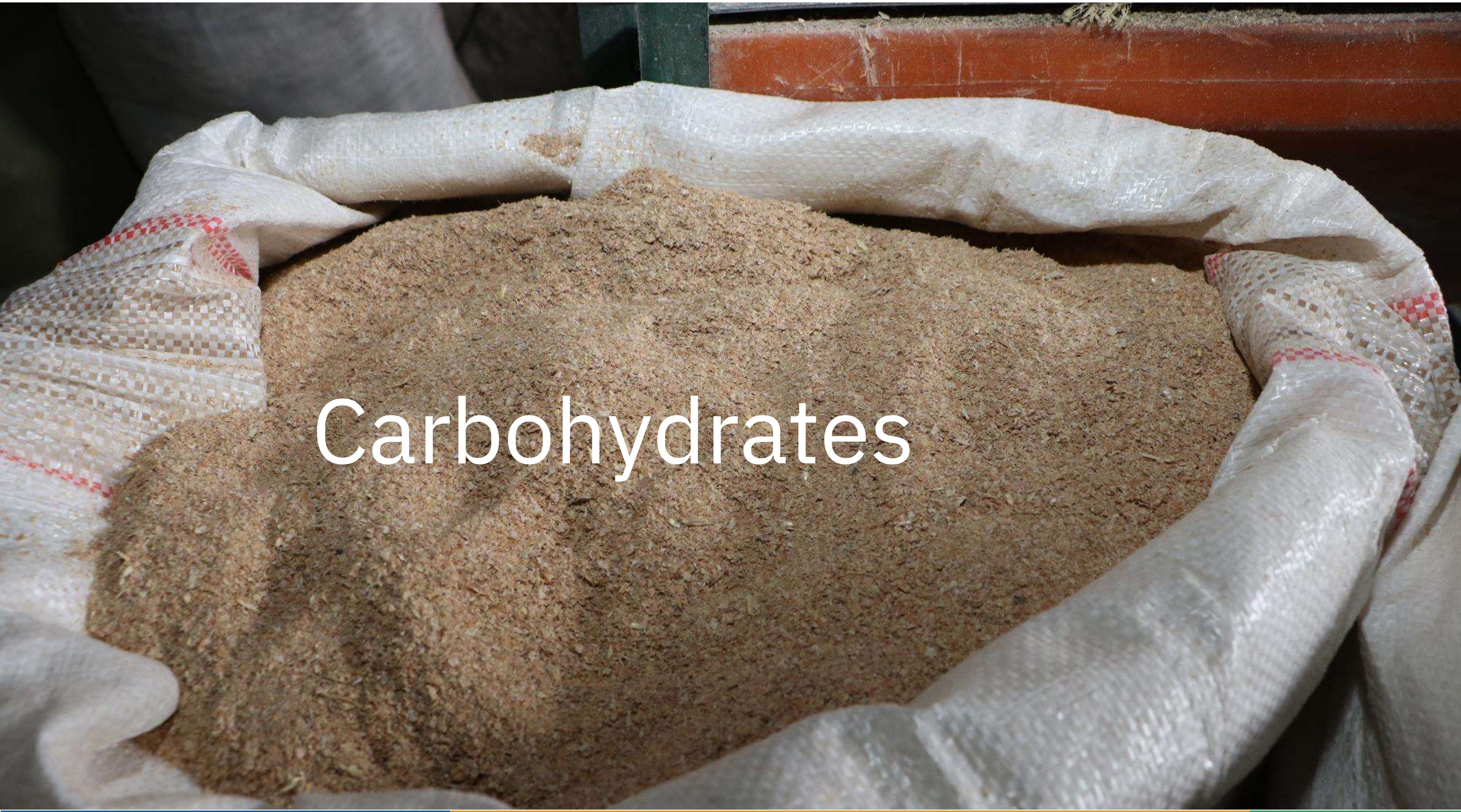
Typical ME values for various feeds

Feed	ME in MJ/kg DM
Peanut hulls	2.7
Rice straw	5.5
Natural grassland overgrown hay	6.5
Napier fresh mature > 120 cm	7.4
Rhodes grass young vegetative	8.4
Leucaena leaves fresh	9.5
Brewers grain dried	10.0
Maize silage DM 30-35%	10.7
Dairy Meal Standard	11.8
Molasses (cane)	12.1
Citrus pulp dry	13.0
Maize grain	13.9
Soybeans (full fat)	14.9

Energy sources

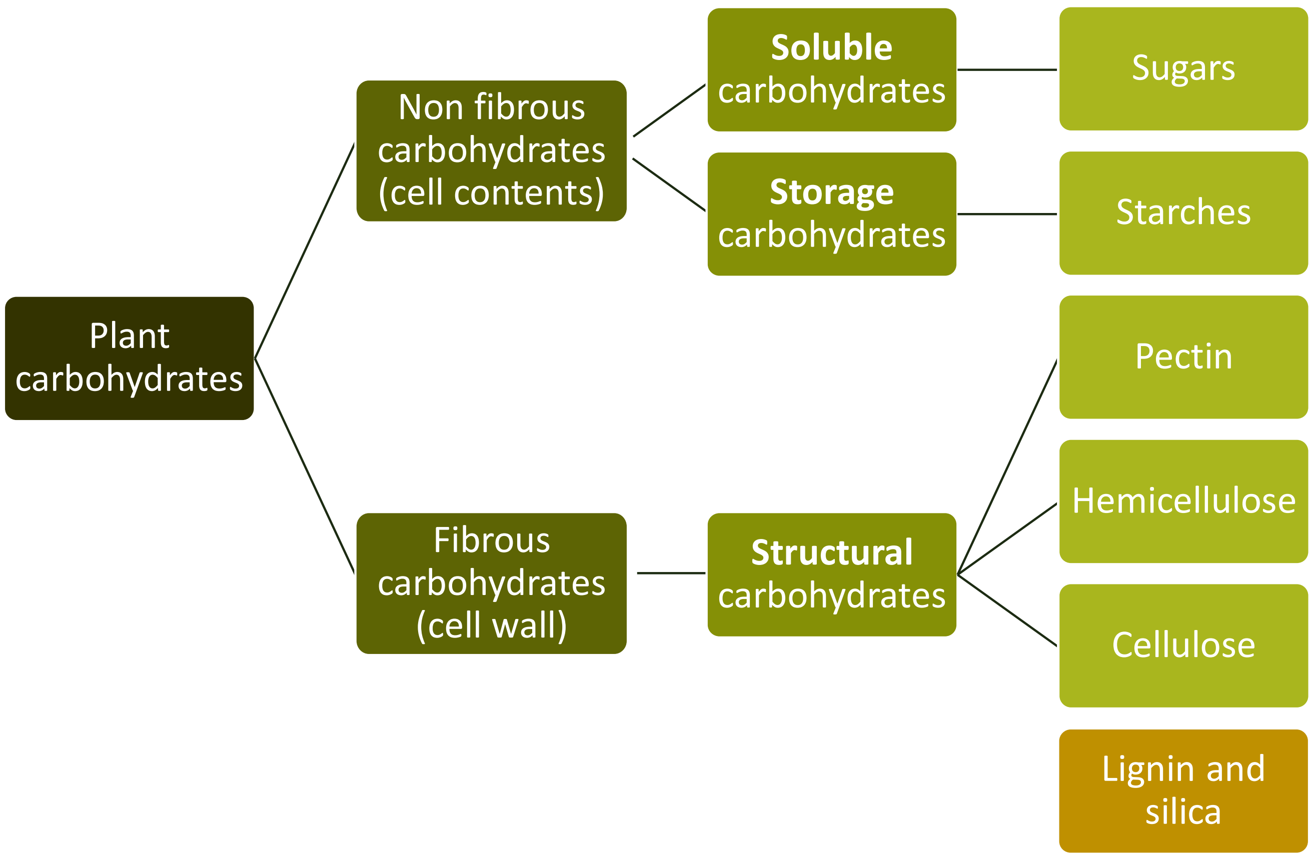
- Carbohydrates
  - Soluble (sugars)
  - Storage (starch)
  - Structural (fibre)
- Proteins
- Fats & oils





Carbohydrates

Carbohydrate types



Breakdown of carbohydrates in the rumen

- Carbohydrates are broken down in the rumen by anaerobic microbes (bacteria, protozoa, fungi)
- Microbes use energy from carbohydrates for their own growth & reproduction
- Microbial activity produces “waste products”
    - Fermentation acids *a.k.a.* **Volatile Fatty Acids** (VFAs)
    - Methane & carbon dioxide

A highly useful “waste product: Volatile Fatty Acids

- Volatile fatty acids (VFAs) are the main source of energy for ruminants

- Main VFAs produced in the rumen:
    - “Acetate” *(Acetic acid – main component in vinegar)*
    - “Propionate” *(Propionic acid)*
    - “Butyrate” *(Butyric acid – also a compound formed in rancid butter)*
    - *Typical molar proportions 70% : 20% : 10%*

VFA production & use in a nutshell

Carbohydrate source	Main VFA produced	Purpose
Fibre	Acetate	General cell metabolism & milk fat synthesis
Sugars Starches Pectin	Propionate	Glucose for cell metabolism. Also milk volume (via lactose) & protein
Sugar Starch	Butyrate	Fat synthesis General energy source

Fats and oils

- Fats & oils are a very high density energy source
  (e.g. 35 MJ ME/kg DM)
- Forages typically contain 2 – 3% fat/oil in dry matter
  (but can be higher at times…)
- Feed no more than 5% fat/oil in the diet – more interferes with microbial digestion in the rumen

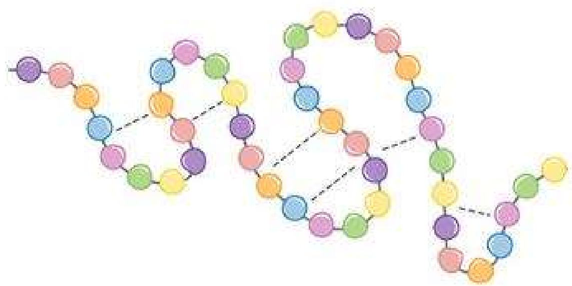
Energy from protein

- Protein can be used as an energy source but this is expensive and biologically less efficient
- The main reason for feeding protein is … well…
  to provide protein!

Protein

Protein

- All proteins contain Nitrogen [**N**] (in addition to C, H & O)
- Any feed components containing N are Crude Proteins
- True proteins are made of long chains of amino acids which are highly important in the diet of all animals
- Proteins exist in all tissues and have many forms, including
    - Body tissue (muscle, bone, nails etc.)
    - Enzymes
    - Hormones
    - Antibodies
    - Milk protein



Measuring protein

- Expressed as Crude Protein (CP)
- CP% is a measure of the amount of nitrogen in a feed
- CP% = Nitrogen (N) x 6.25
  - (x 6.25 because the mean N content of proteins = 16%)

Components of crude protein

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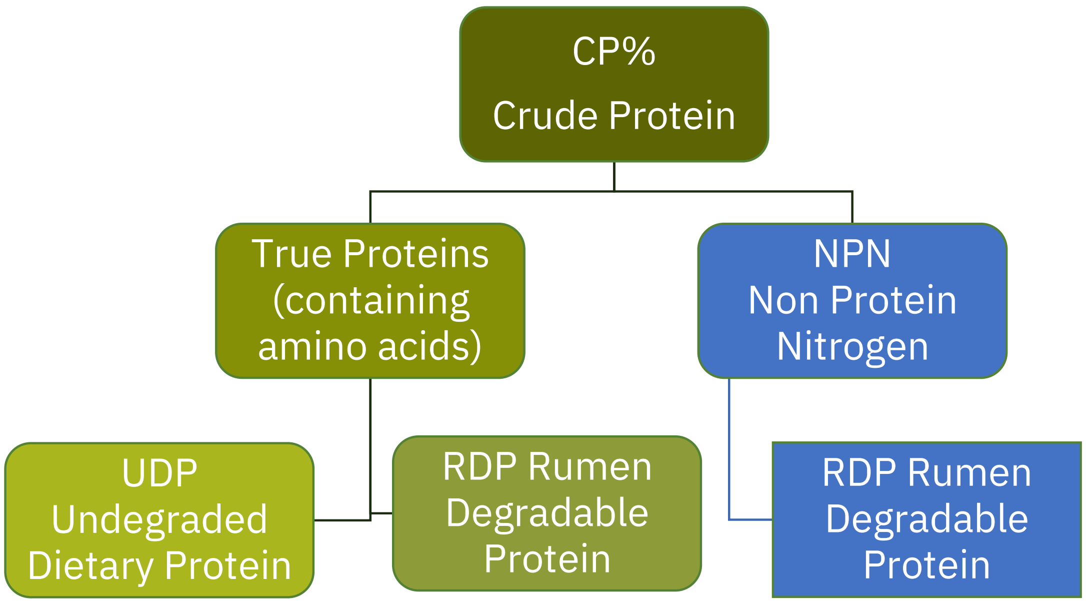

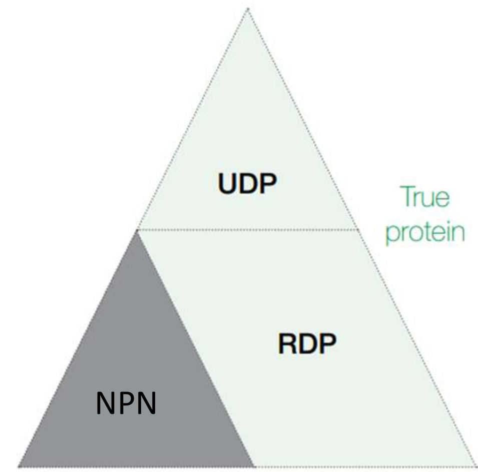

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Non protein nitrogen (NPN)

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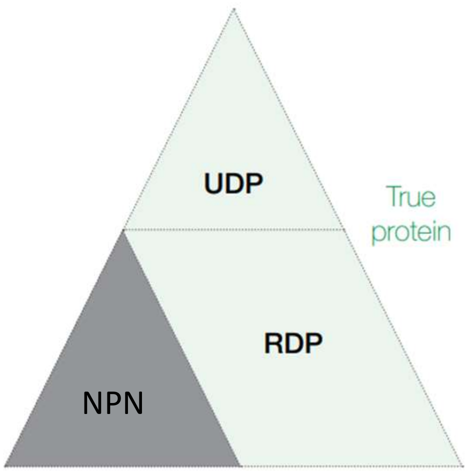
- Any feed N that is NOT a true protein
  (i.e. N compounds that do not contain amino acids)
- Rumen microbes **may** be able to use NPN to build their own protein, but only if there is sufficient **energy** present in the diet
- Sources of NPN include:
  - Urea
  - Nitrate
  - Ammonia in silages
- But due to rapid breakdown NPN can lead to ammonia poisoning when fed in excess!!!!



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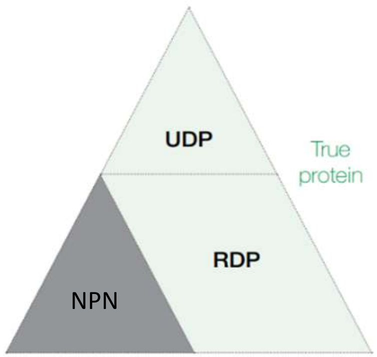
Rumen degradable protein (RDP)

- Protein that is broken down in the rumen by microbes
- RDP is used to grow more microbes which are high in protein (microbial protein)
  - Microbial protein is main source of true protein for ruminants
  - But microbial protein production also requires **energy** so energy and RDP supply must be in balance!!



- Excess feed protein is degraded to urea in the liver and recycled or excreted in urine. This process requires energy so feeding too much protein is counter-productive and depresses animal performance

Undegraded Dietary Protein (UDP)

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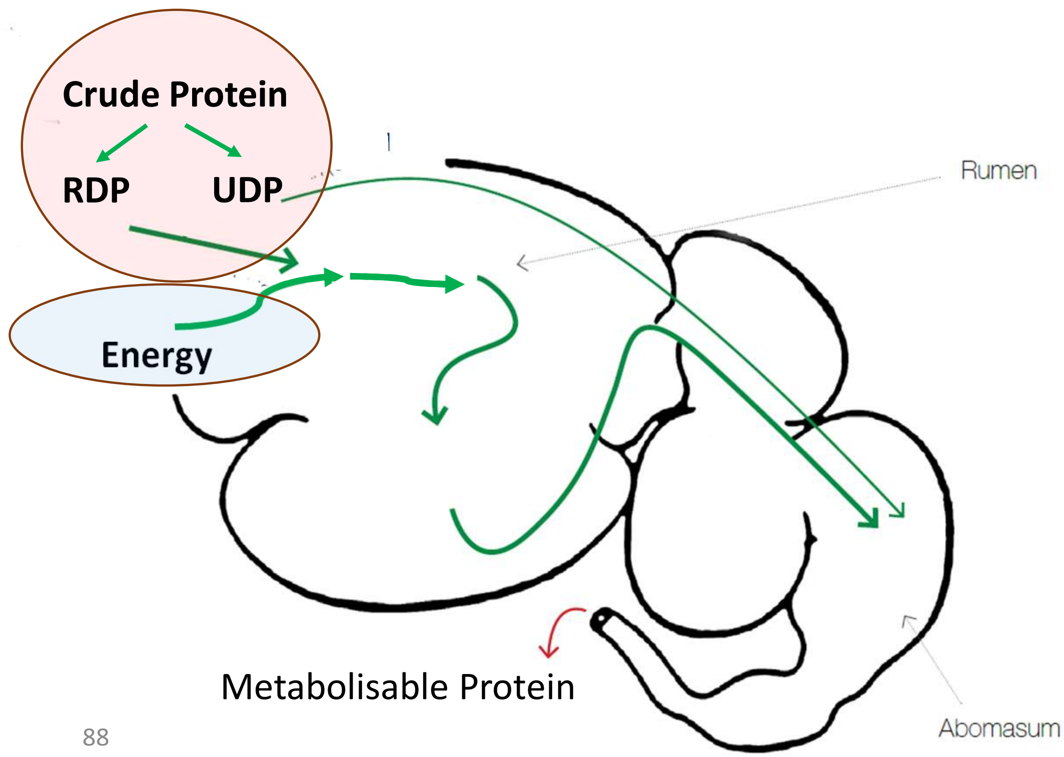
- Also known as '*Bypass protein*'
- UDP is protein that escapes breakdown by microbes in the rumen – can be due to:
    - Type of protein and/or
    - Rapid rate of digesta flow through the rumen
- Most UDP is digested in the abomasum and absorbed from the small intestine for use by the cow
- Some UDP is undigestible and is excreted in manure
- The level of UDP in a feed can be increased by heat treatment (e.g. direct heating or heat generated by pelleting a feed)

Simplified protein metabolism in the rumen

- Rumen microbes ferment feed protein: RDP →ammonia → microbial protein
- Some feed protein escapes breakdown by microbes (UDP)
- Microbes and UDP enter abomasum
- Digestion of microbes and UDP provides amino acids for absorption = Metabolisable Protein (MP)



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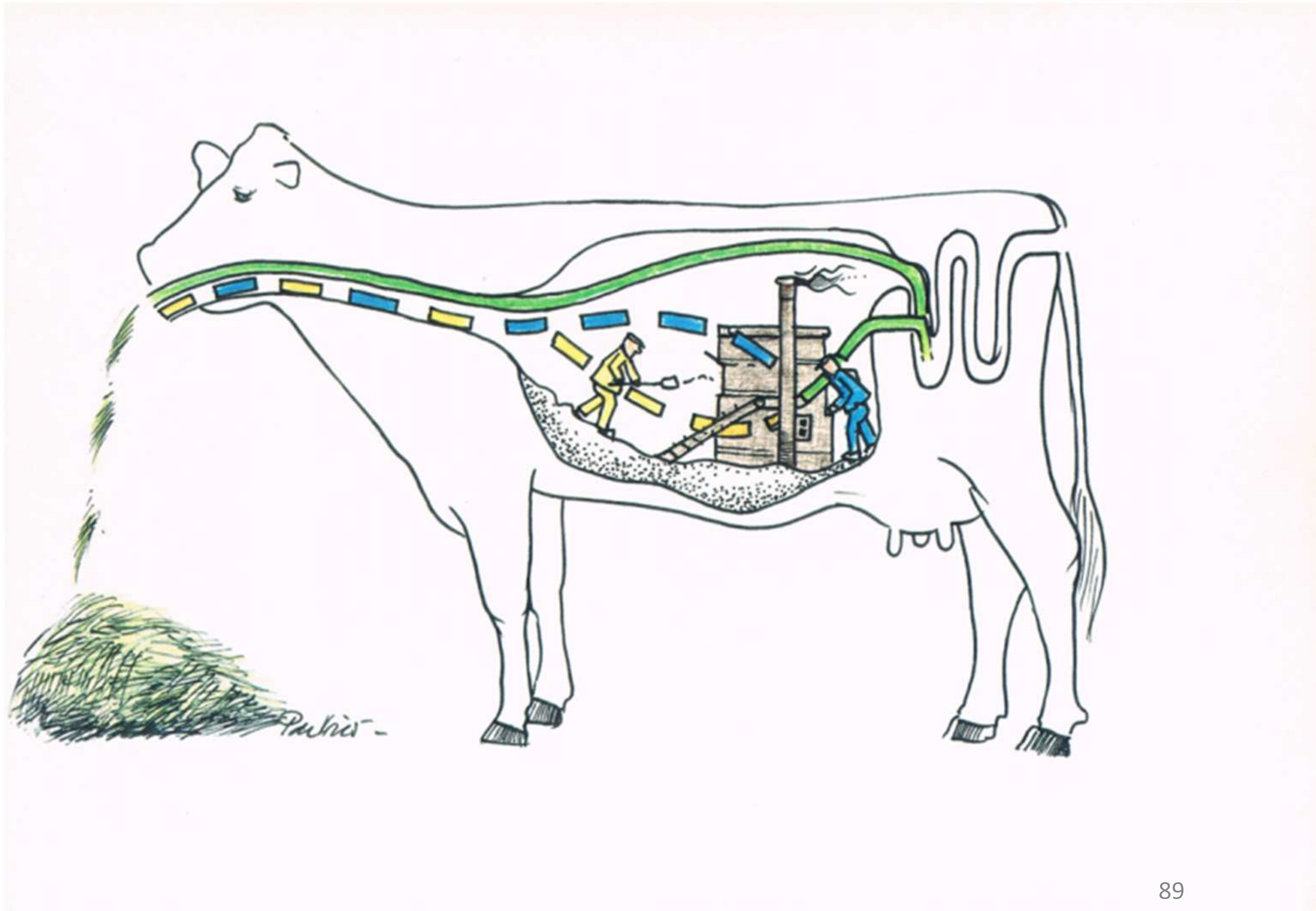
Optimising microbial protein

For optimal production of microbial protein we need the correct balance between :

- Fermentable carbohydrates
- ‘Fermentable nitrogen’ = rumen degradable protein (RDP)



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More on metabolisable protein

- Digestible true proteins in microbial protein + UDP that are absorbed from the small intestine
- True protein that the cow finally absorbs and uses for maintenance, production, growth & reproduction
- Microbial protein can provide all the protein required for cows producing up to ~ 30 litres milk a day
- Additional UDP ('bypass protein') may be justified when milk production exceeds 30 litres a day

Metabolisable Protein in feed

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- MP cannot be measured in a feed analysis
- The amount of MP that can be produced from a diet depends on complex dietary interactions and is therefore not constant
- MP supply can be predicted with computer models such as Rumen8
- Crude Protein is still a common and useful measure for feed analysis – typical requirement 120-160 g CP per kg DM

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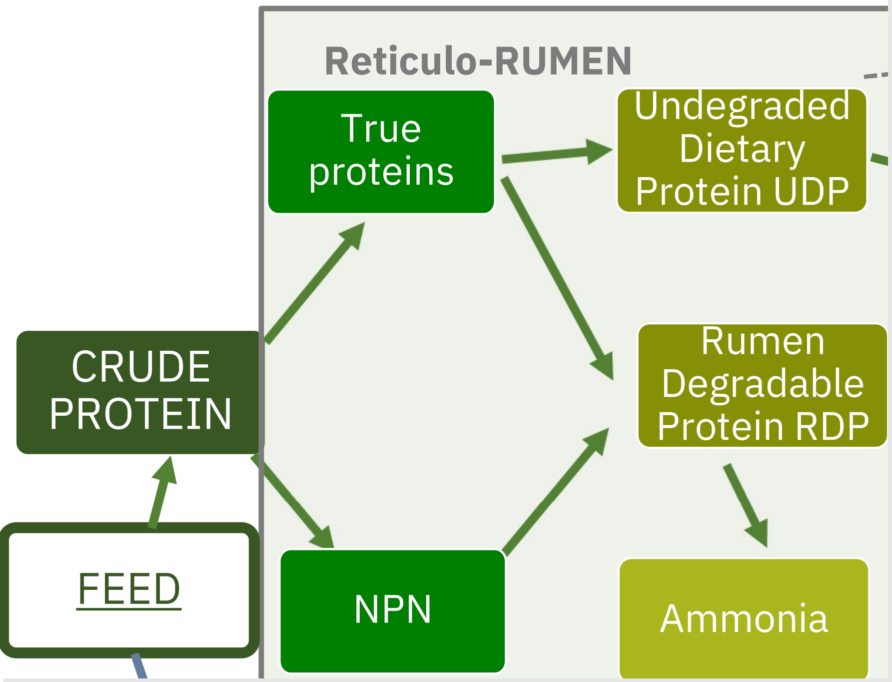
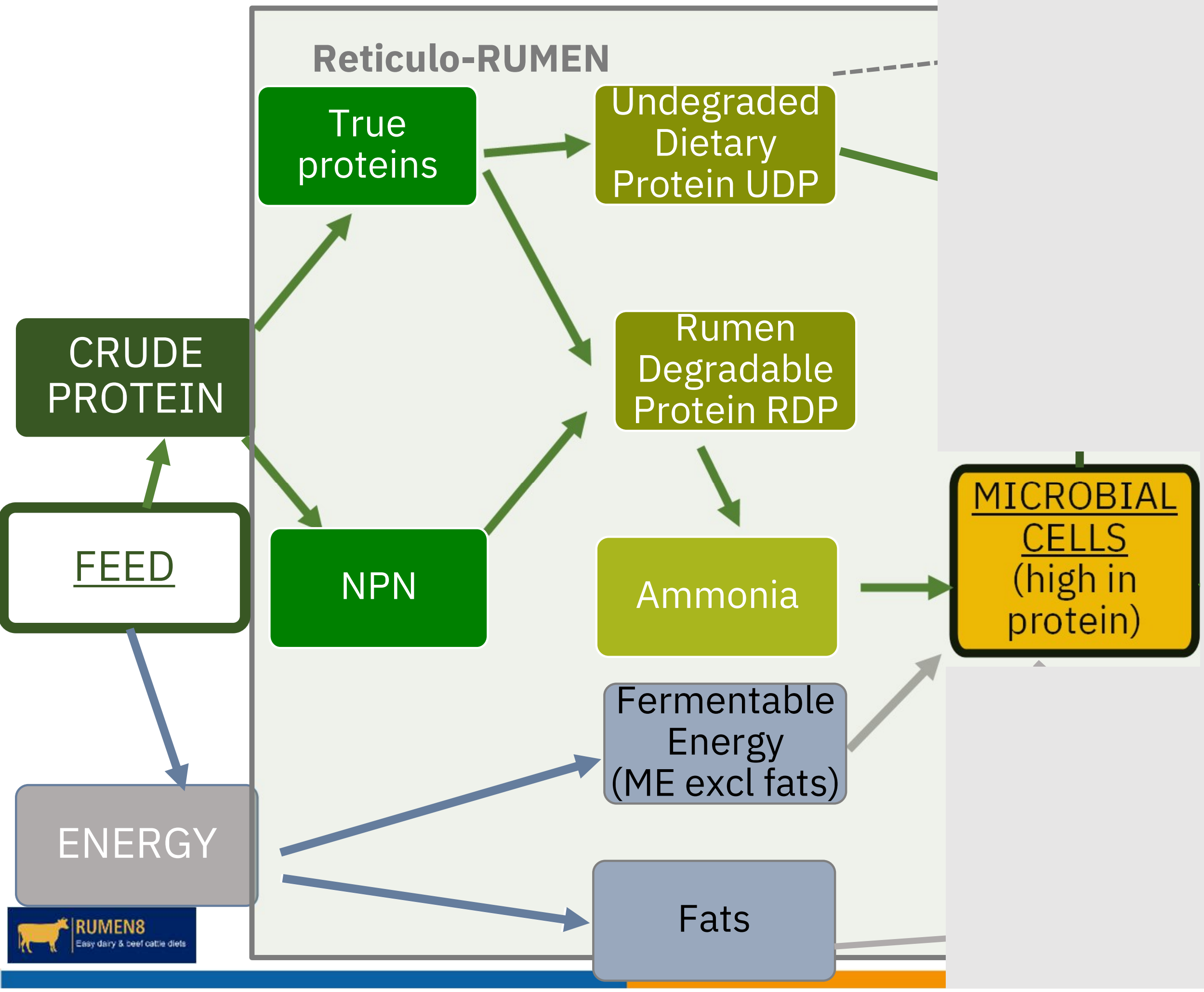
Excess protein

- Feeding protein in excess of requirements is bad practice because:
  - protein is expensive
  - excess protein needs to be removed from the body which requires energy which therefore decreases animal performance
  - excess dietary protein leads to high N in urine which can lead to urine burns in pasture and environmental pollution

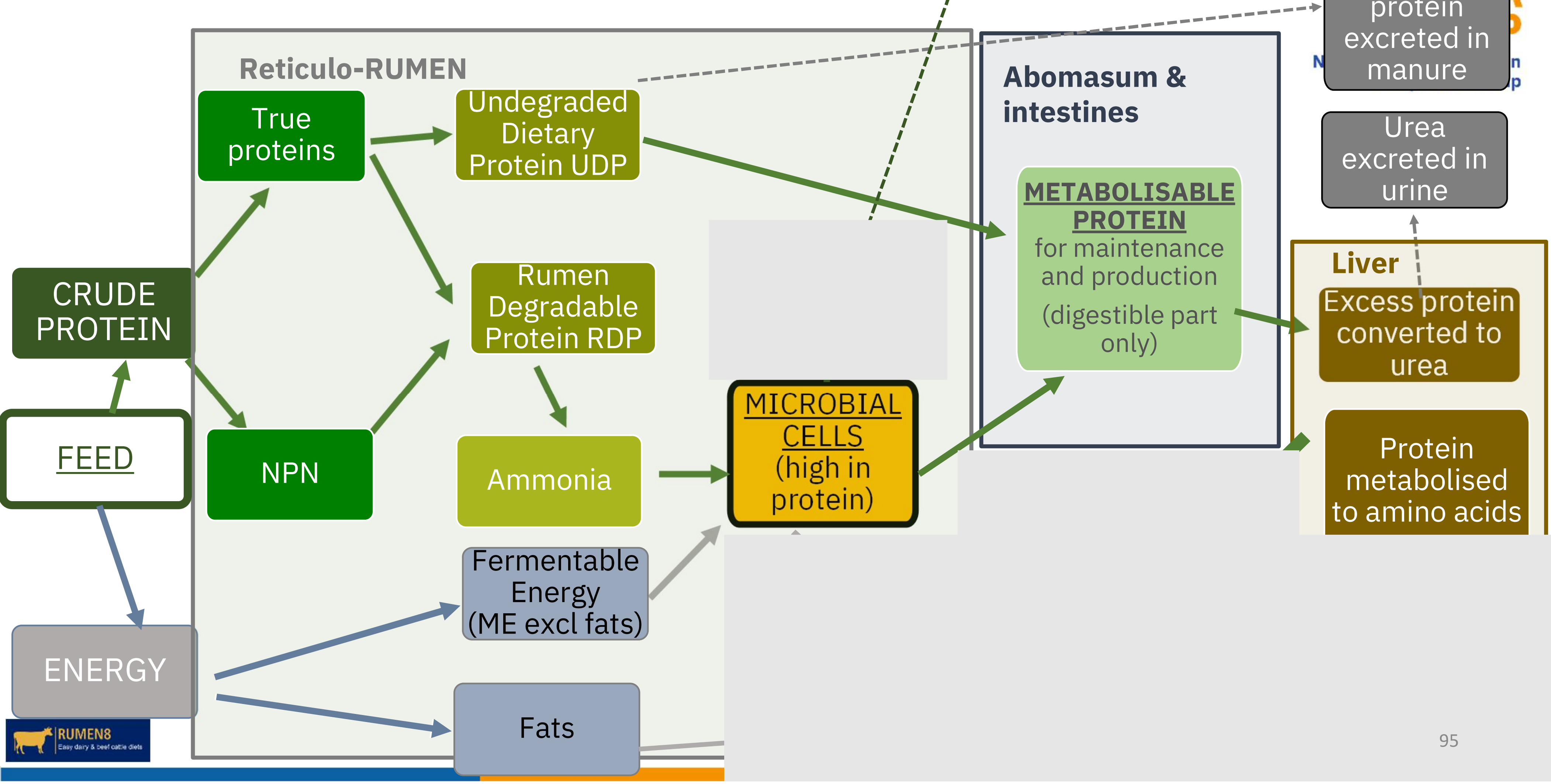
Simplified nutrient use



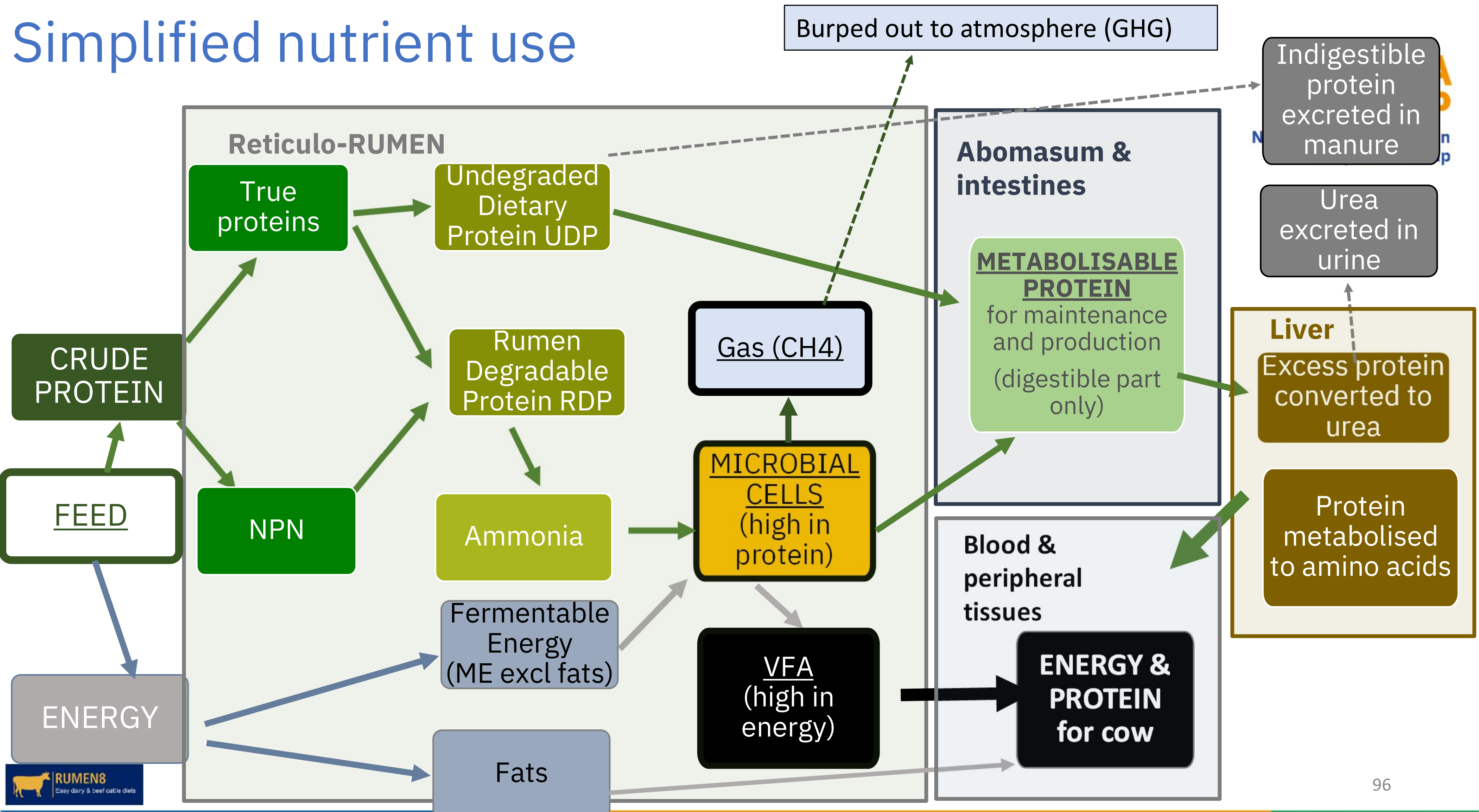
Simplified nutrient use



Simplified nutrient use



Simplified nutrient use




Fibre

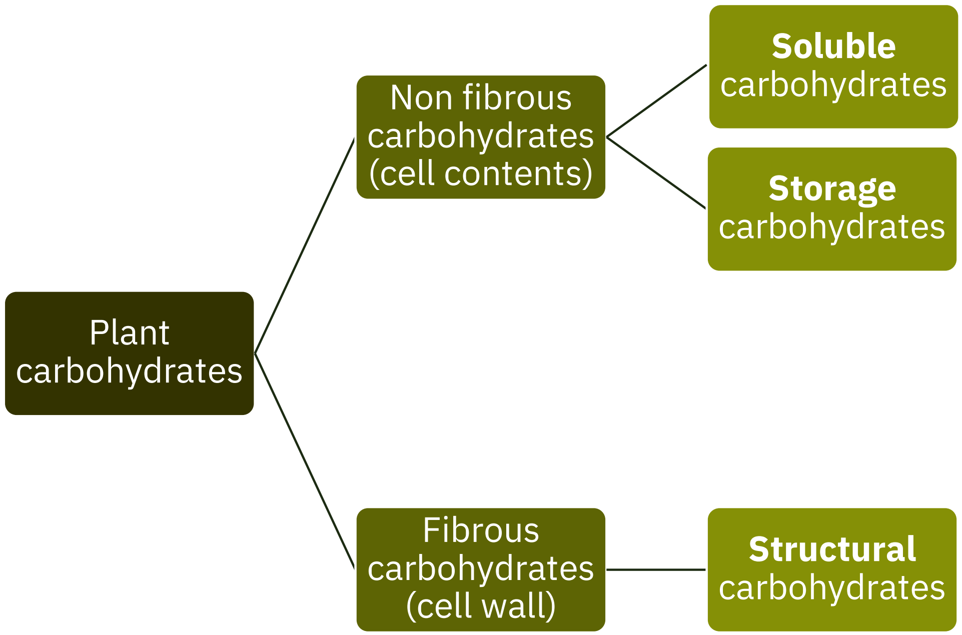
Cow turns away
from too much fibre

Fibre is essential for rumen health

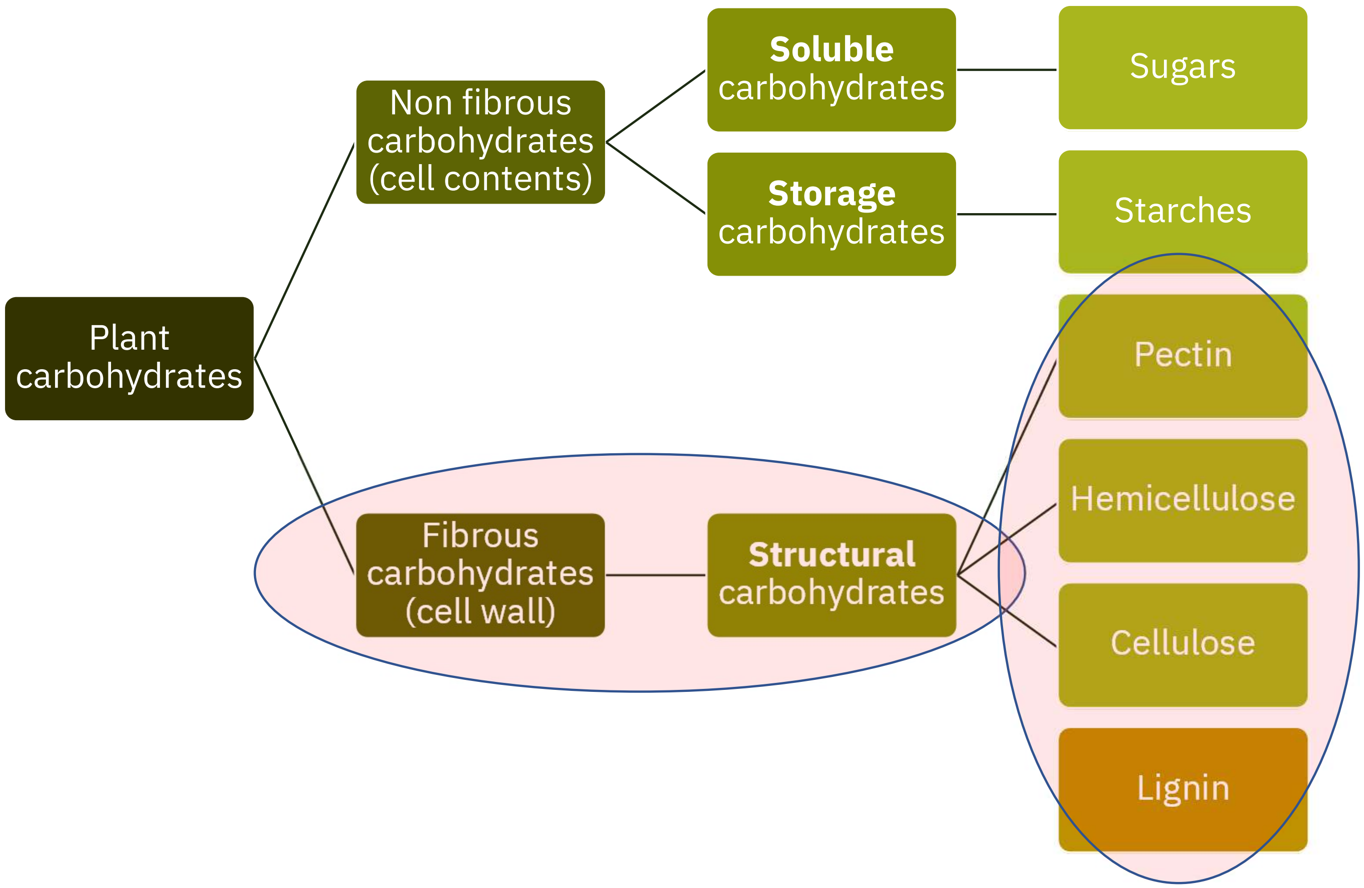
Fibre is essential for rumen function and health

- Long fibre (**physically effective fibre**) stimulates chewing and saliva production
- It stimulates rumen mixing and rumination
- Microbes cling to the fibrous rumen mat and fibre particles
- Fibre slows the passage of feed through the rumen
- Microbial breakdown of fibre produces the VFA acetate, which is a main energy source for cow metabolism and also drives milk fat production

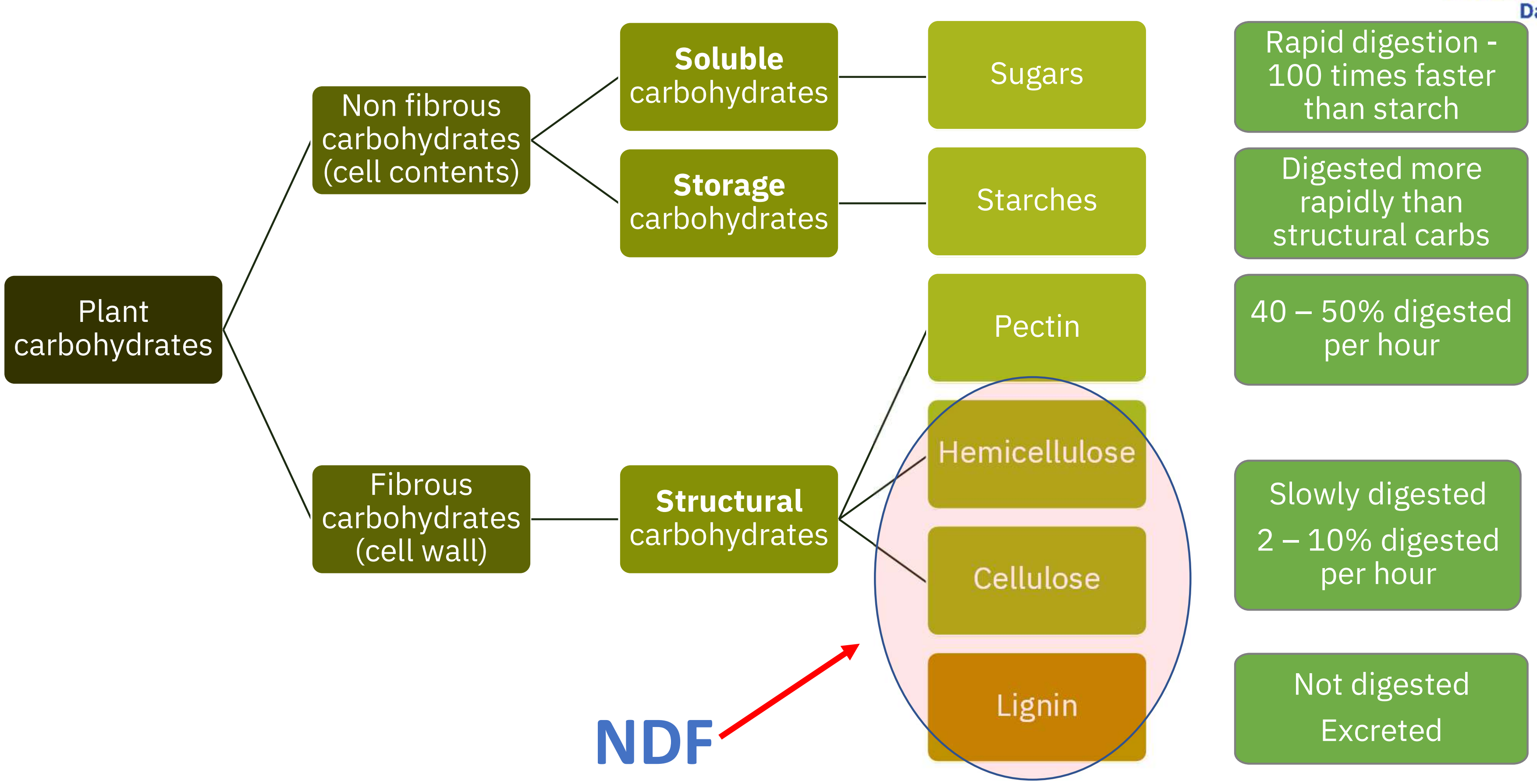
Fibre is made mostly of carbohydrates



Different components to fibre



Different components to fibre



Rate of carbohydrate breakdown

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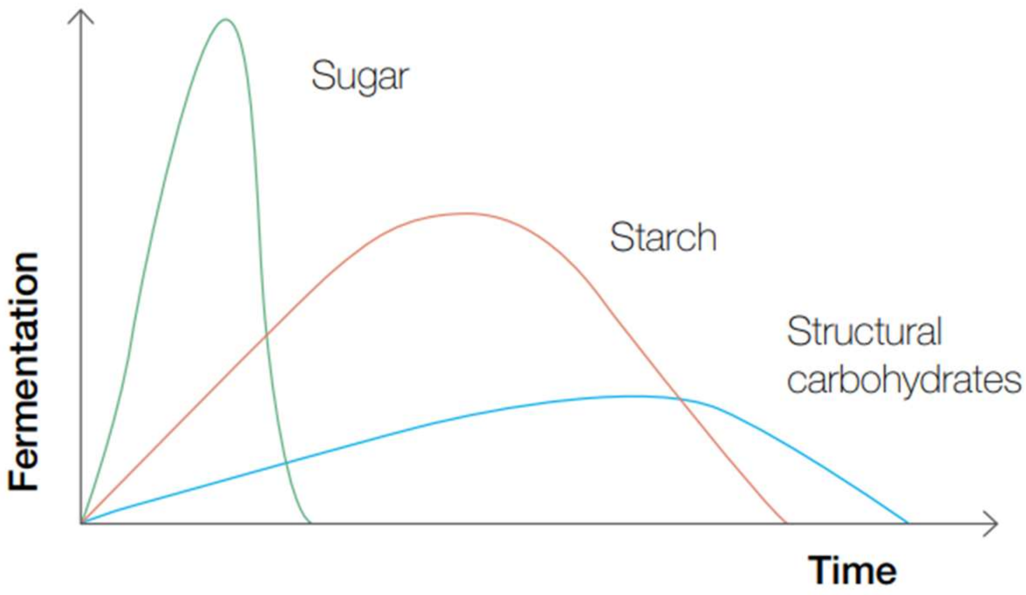

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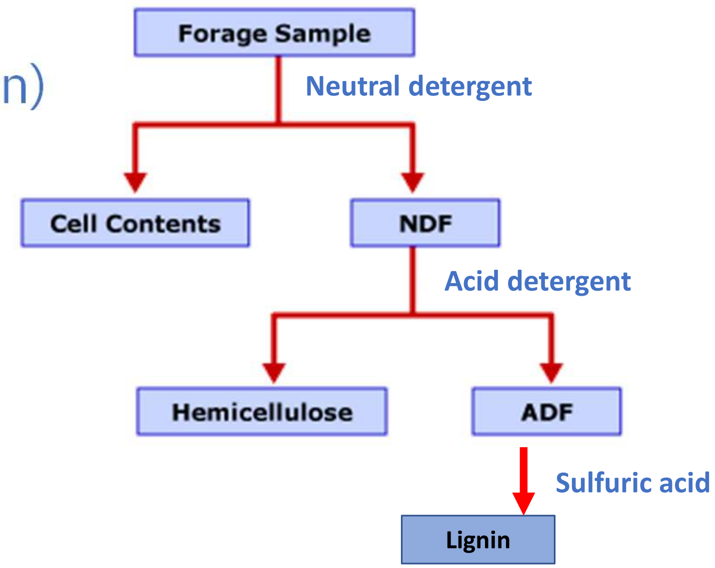
From Feeding Dairy Cows 5th Edition

Measuring fibre

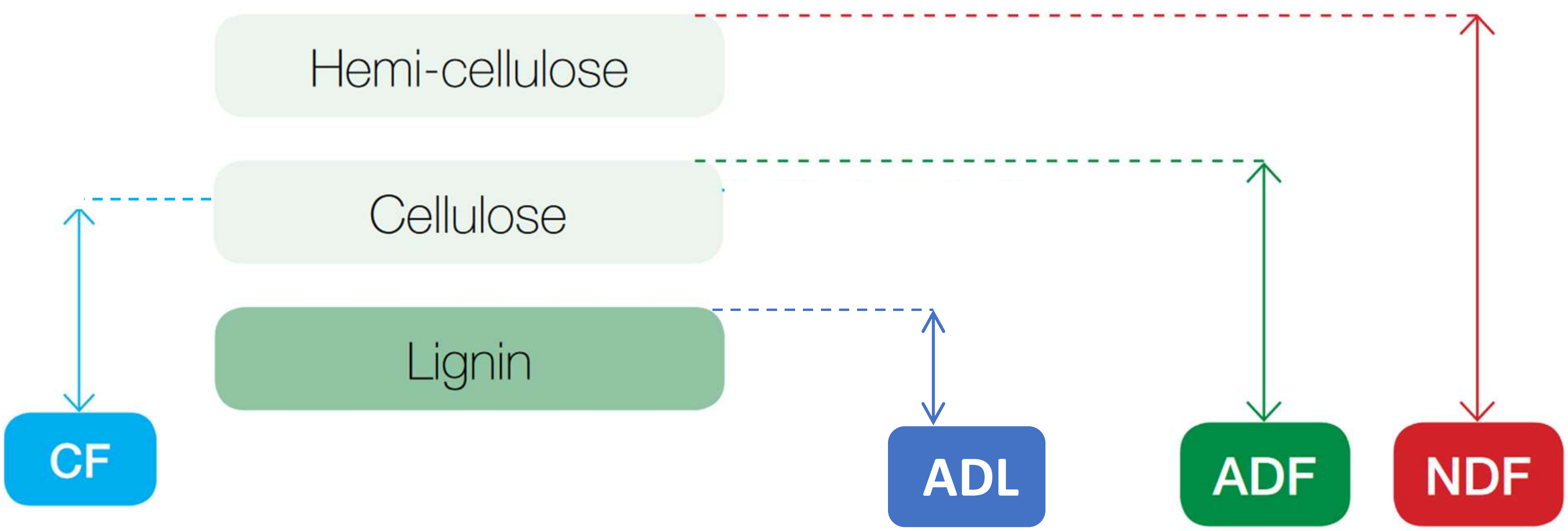
- **Neutral Detergent Fibre (NDF)**
- Measure of total fibre (hemicellulose, cellulose and lignin)
- Indicates how bulky (fibrous) a feed is
- Indicator of potential feed intake - high NDF feed may result in lower intake due to slow movement through the rumen

- **Acid Detergent Fibre (ADF)**
- Measures the poorly digestible and indigestible fibre (cellulose and lignin)
- Indicator of digestibility – high ADF = low digestibility

- **Lignin**
- Measures the indigestible part of fibre



Measuring fibre

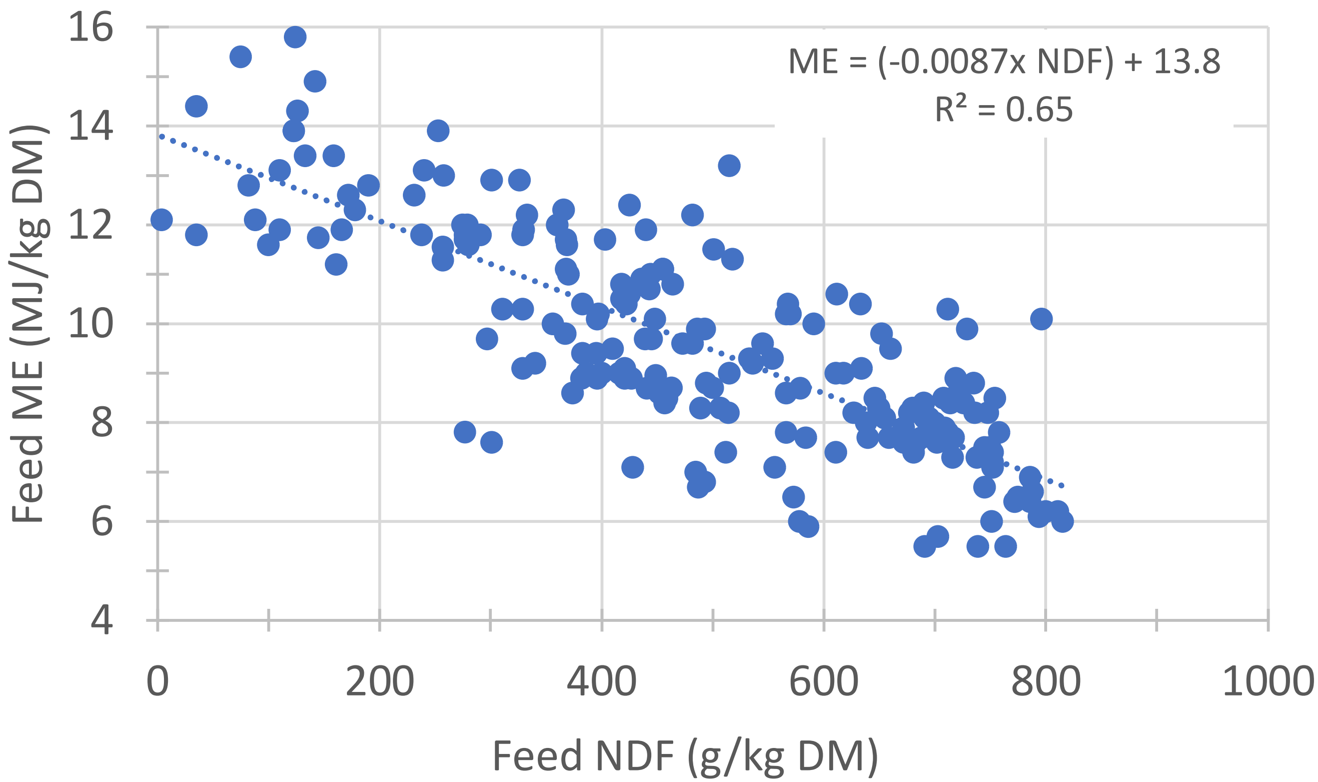


Physically effective NDF (peNDF)

- Long particles are required for NDF to be physically effective (i.e. stimulate animal to ruminate)
- Physically effective NDF promotes chewing, salivation and rumination – all essential for rumen health
- peNDF is a function of NDF content & particle size (fibre length).
- See examples below

Feed	NDF g/kg DM	peNDF g/kg DM	Comment
Lucerne hay	500	475	95% of NDF is physically effective
Lucerne hay - ground	500	150	Only 30% of NDF is physically effective
Brewers grain	590	200	Only 34% of NDF is physically effective

Relationship between NDF and ME



NDF	ME
200	12.1
400	10.3
600	8.6
800	6.9

Minerals & vitamins

Minerals

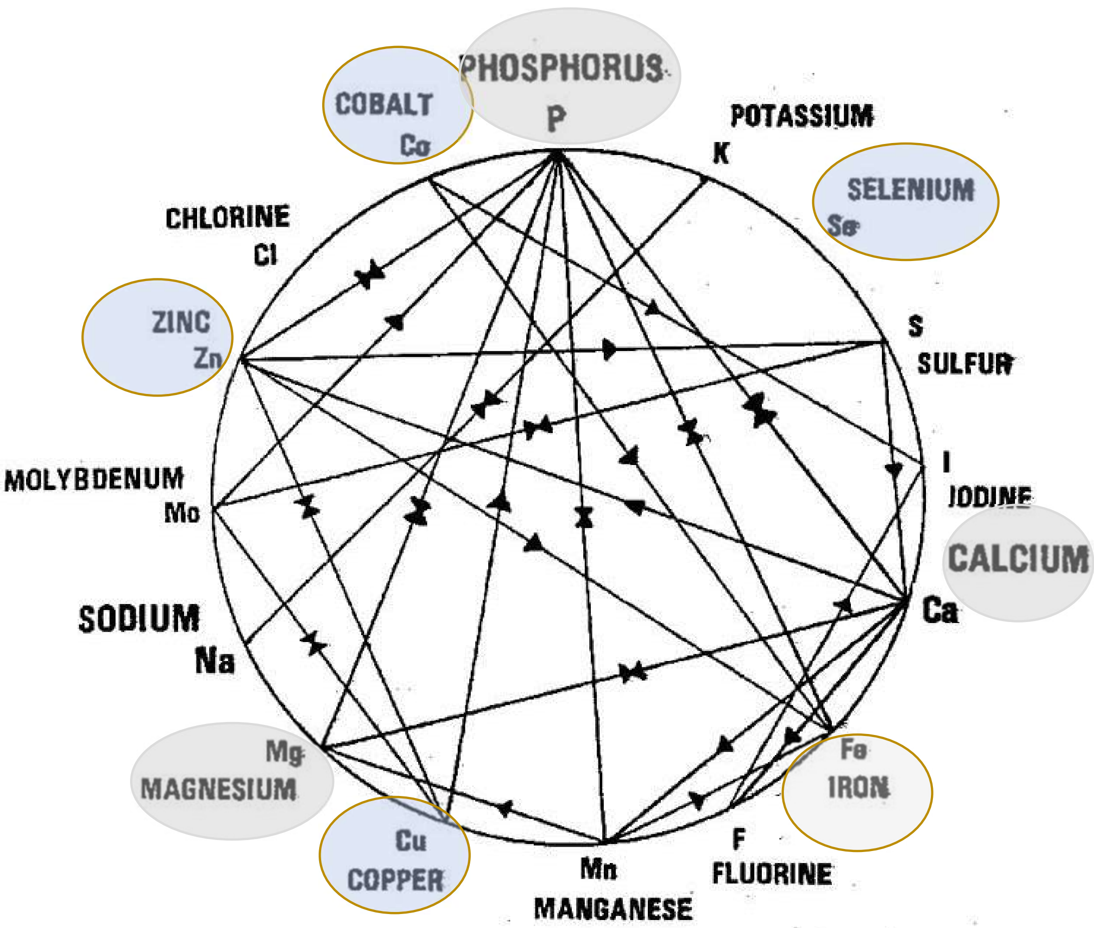
- Make up 3 – 4% dry matter of the body
- Essential for animal health
- Perform many roles in the body, including
    - Structural (skeleton)
    - Water balance and electrolytes
    - Many essential metabolic functions

Minerals required

- **Macro Minerals** = minerals required in large quantities
  - Ca, P, Mg, K, Na, Cl and S
  - Measured in g/kg DM (or sometimes as % in feed DM)
- **Micro Minerals** = minerals required in small amounts
  - Cu, Fe, I, Mn, Zn, Se and Co
  - Measured in mg/kg DM

- Minerals can interact with other nutrients and each other!!...

Complex interactions!



Vit D
Vit E
Vit A
Vit K

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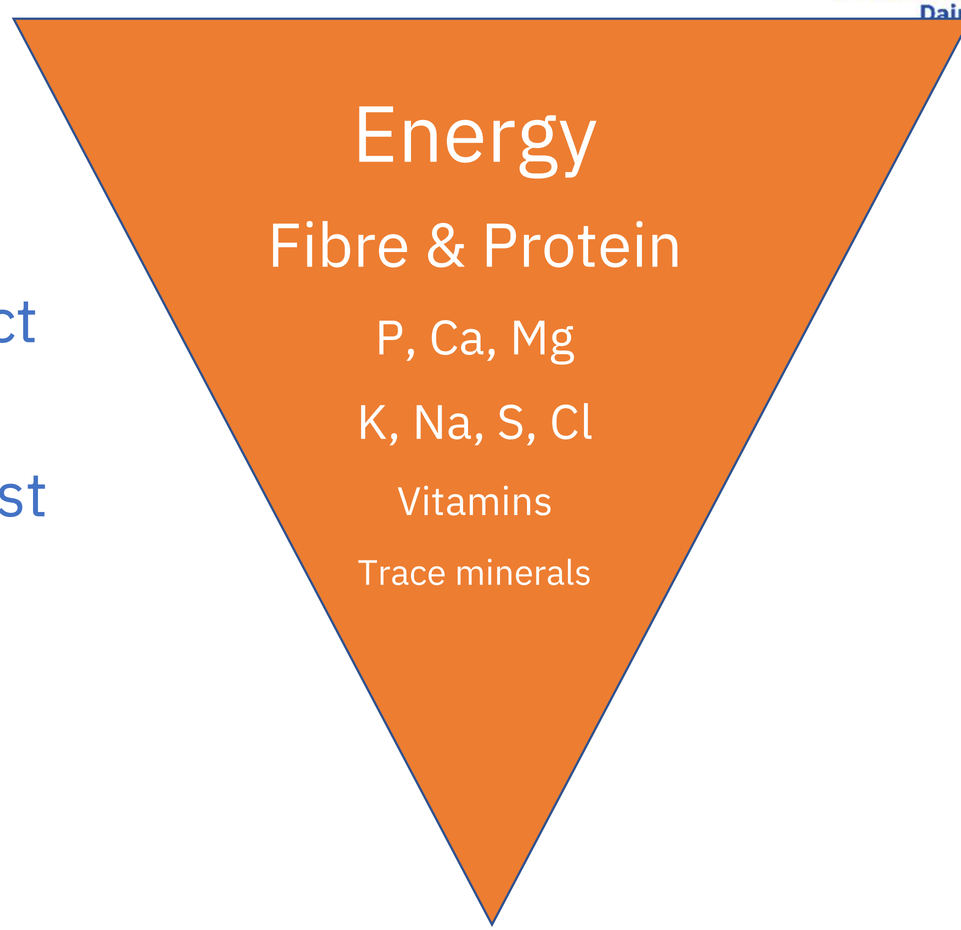
The feed 'pyramid'

- Look after your livestock
- Energy and nutrients are required in the correct amounts and in balance
- But financial viability must be considered always



Summary

- Feed is made up of water and dry matter (DM)
- Dry matter contains all the energy and nutrients
- Dry matter digestibility (DMD%) is an important indicator of nutrient availability
- Key components of feeds are
  - Metabolisable Energy (ME in MJ/kg DM)
  - Fibre (NDF g/kg DM, peNDF)
  - Protein (CP g/kg DM)
    Metabolisable Protein supply (MP) is calculated in computer models
  - Minerals and vitamins


Q & A
Discussion

Part 1E
Requirements for energy, nutrients & water

Feeding Standards

- Requirements for energy and nutrients are published in various countries to predict nutrient requirements for dairy cows
- These are also used in the Rumen8 software that is part of this course

Feeding standards evolve!

- But no international uniformity
- They don’t all use the same “language”….
- For example metabolisable energy vs net energy vs fodder units (e.g. “VEM” and “UF”)
- Also: megajoules (MJ) vs megacalories (Mcal)
- Can be confusing for new entrants

Water

Why is water required?

- Water is essential for life
- Cows need water for many functions including:
  - Temperature regulation
  - Digestion
  - Nutrient transport
  - Metabolic processes (chemical reactions)
  - Waste removal

How much water?

- Water requirement is influenced by
  - Cow live weight
  - Feed dry matter consumption
  - Water content of feed
  - Milk production
  - Temperature and humidity
  - Water quality

- Restricted water intake results in decreased milk production!!

Rules of thumb – DRY cows

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Cow	Daily water requirement
Non-pregnant (empty) cows in cool environment (less than 15°C)	• Around 3.5 litres water per kg DM consumed
Pregnant cows in warm environment (21 - 25°C)	• Up to 7 litres water per kg DM consumed

In Hot environments >25 ℃ – more water required!

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Rules of thumb – LACTATING cows

Cow	Daily water requirement
Lactating cow	• 6 litres water per kg DM consumed • **Plus** an additional 1 litre water per litre of milk produced • **Plus** additional allowances for hot weather

Example water requirements

- Dairy cow consuming 13 kg feed DM per day
- Producing 14 litres milk per day
- Moderate temperatures
- Needs a minimum of
  (6 L x 13) + (1 L x 14) + (0 L)
  = 92 litres

- **Multiply by the number of cows in the herd!!**

Key message
WATER

- Ensure an unlimited supply of good quality drinking water is available at all times

PLEASE CALCULATE: How much water needed for these two groups per day?

- 10 dry pregnant cows: DM intake 10 kg each, warm environment (21 - 25°C)
- 35 lactating cows: milk 20 litres/d, feed intake 16 kg DM, hot day

Nutrient requirements -Energy

What is energy used for?

- Maintenance metabolism (bodily functions incl. digestion!!)
- Physical activity (walking, standing etc.)
- Growth (live weight gain)
- Milk production
- Pregnancy
- Energy storage (body fat)

Efficiency of energy use

- Cows don't always achieve the same level of performance from the same amount of energy (megajoules (MJ) of metabolisable energy)
- Cows are more efficient when they are
  - Eating a higher quality diet (higher ME per kg DM intake)
  - Lactating (compared to dry cows)

Maintenance energy

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The energy required to simply stay alive

- Needed for all body processes including:
  - Breathing
  - Rumination
  - Digestion!
  - Blood circulation
  - Temperature regulation

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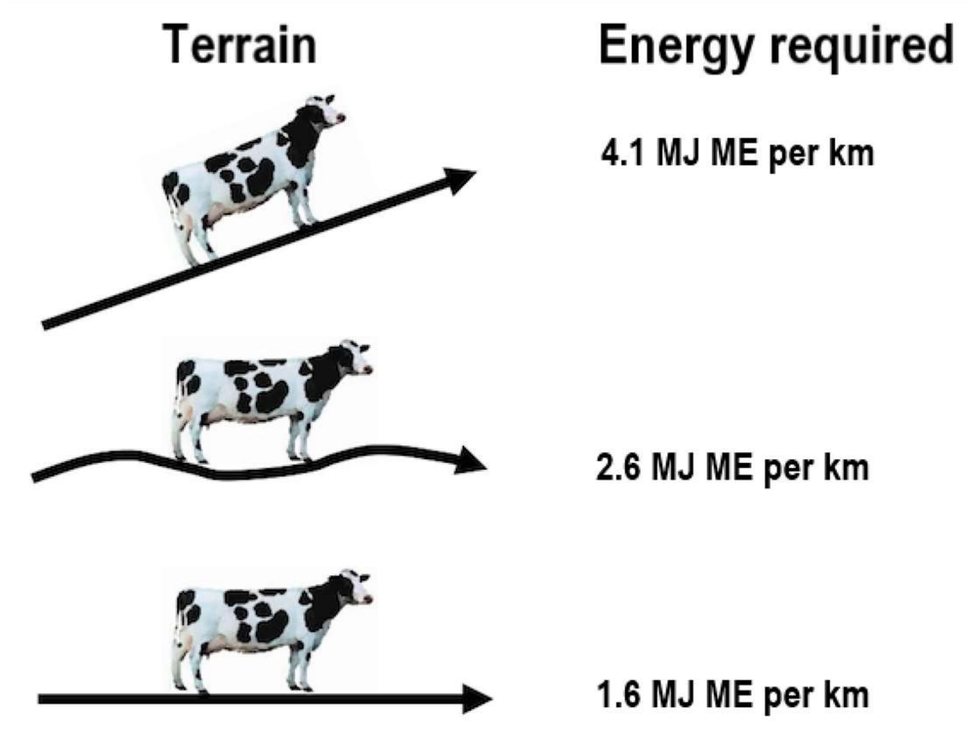
Maintenance requirement

ME required for maintenance depends on:

- Feed quality
- Live weight
- Whether cows are dry or milking
- Milk production
- Whether cows are grazing or not
- Distance walked & slope of terrain



For 600 kg cow & 11 MJ ME/kg DM

Maintenance requirements (MJ ME)

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Effect of live weight, milk production & activity level (mean diet ME 10)

Cow	Cut & carry			Grazing*		
LW kg	10 L	15 L	20 L	10 L	15 L	20 L
400	53	53	54	66	67	67
500	62	62	63	78	79	79
600	70	71	71	90	91	91

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*Grazing: walking 5 km per day over undulating terrain

Physical activity is part of maintenance requirements

- Energy required to walk to and from milking and during grazing depends on:
    - distance and terrain
    - live weight
    - diet quality
- Cows can walk lots while grazing!!

Effect of live weight and terrain on ME for walking

MJ ME required/km walked			
Diet Quality 10 MJ/kg DM			
Cow	Slope of terrain		
LW kg	Flat	Undulating	Steep
400	1.2	1.9	2.9
500	1.4	2.3	3.6
600	1.7	2.8	4.4

Effect of diet quality on total ME requirements

Cow LW kg	Cut & carry 9 MJ ME/kg DM			Cut & Carry 11 MJ ME/kg DM		
	10 L	15 L	20 L	10 L	15 L	20 L
400	114	145	177	108	137	167
500	123	154	185	116	145	175
600	132	162	194	124	153	182

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But can our cows eat all this?

kg DM required per day to provide the level of ME shown in previous slide

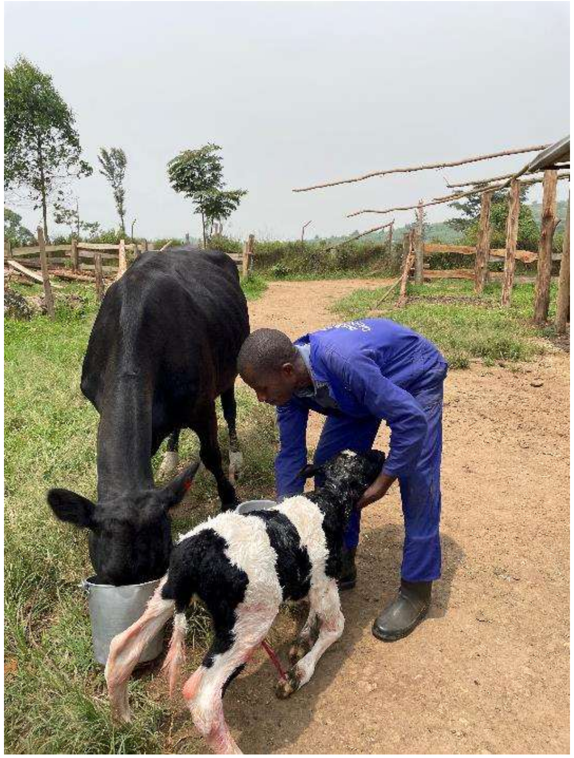
Cow LW kg	Cut & carry 9 MJ ME/kg DM			Cut & Carry 11 MJ ME/kg DM		
	10 L	15 L	20 L	10 L	15 L	20 L
400	12.7	16.1	19.7	9.8	12.5	15.2
500	13.7	17.1	20.6	10.5	13.2	15.9
600	14.7	18.0	21.6	11.3	13.9	16.5

Intake of DM as % of LW

Cow LW kg	9 MJ ME/kg DM			Cut & Carry 11 MJ ME/kg DM		
	10 L	15 L	20 L	10 L	15 L	20 L
400	3.2%	4.0%	4.9%	2.5%	3.1%	3.8%
500	2.7%	3.4%	4.1%	2.1%	2.6%	3.2%
600	2.4%	3.0%	3.6%	1.9%	2.3%	2.8%

Pregnancy

Month of gestation	Energy required by the pregnant uterus (MJ ME/d)
1	<1
2	<1
3	1
4	2
5	3
6	5
7	9
8	17
9	33
Term	43



Milk production

- Energy required for milk production depends on:
  - Milk volume
  - Fat, protein and lactose content
- The higher the milk components the more energy is required per litre milk

ME for milk production depends on milk composition

ME required per litre of milk at varying milk components
(based on diet of 10 MJ/kg DM)

MJ per litre milk		True protein (% mv)					
		3.0	3.2	3.4	3.6	3.8	4.0
Fat (%mv)	3.0	4.83	4.90	4.99	5.08	5.16	5.25
	3.5	5.17	5.25	5.34	5.42	5.51	5.59
	4.0	5.51	5.60	5.68	5.76	5.85	5.93
	4.5	5.85	5.94	6.02	6.11	6.20	6.28
	5.0	6.19	6.28	6.36	6.45	6.54	6.62

Note: 1 litre of milk weighs ~1.03 kg

Condition score gain

Energy required for body condition score gain depends on:

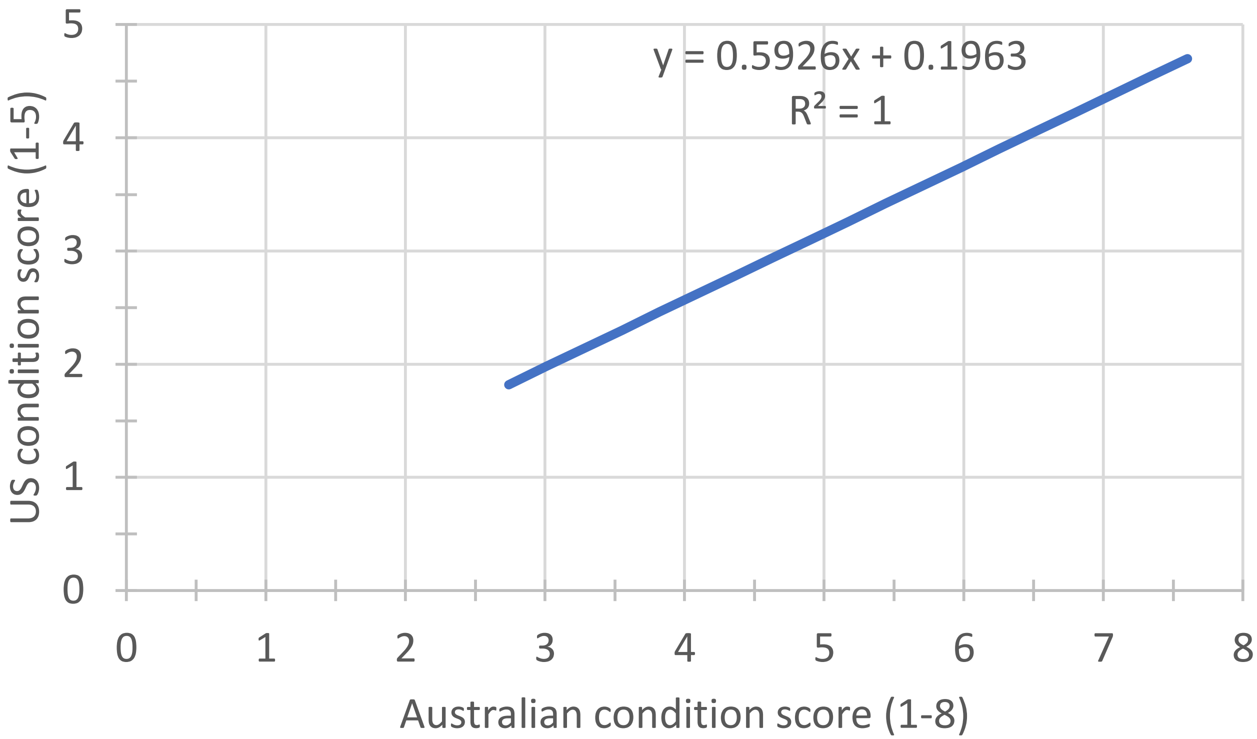
- starting live weight
- starting condition score
- whether lactating or dry

- US Penn State system 1-5 score
- Australia/NZ system 1-8 score

A comparison of body condition score targets at different stages of lactation between the Australian (1-8) and Penn State (1-5) systems

Stage of lactation	Days in milk	Mean Australian BCS goal	Mean Penn State BCS goal
Calving	0	5.0	3.5
Eary lactation	1 to 30	4.5	3.0
Peak milk & mating	31 to 100	4.3	2.75
Mid lactation	101 to 200	4.5	3.0
Late lactation	201 to 300	4.75	3.3
Dry off	> 300	5.0	3.5
Dry off	-60 to -1	5.0	3.5

Australian vs US body condition score for dairy cows



J. Dairy Sci. 87:3076–3079

Relationships Among International Body Condition Scoring Systems

J. R. Roche,[1] P. G. Dillon,[2] C. R. Stockdale,[3] L. H. Baumgard,[4] and M. J. VanBaale[4]
[1]Dexcel, Hamilton, New Zealand
[2]Teagasc Moorepark, Fermoy, Co., Cork, Ireland
[3]Primary Industries Research Victoria–Kyabram, Kyabram, Victoria, Australia 3620
[4]Department of Animal Sciences, The University of Arizona, Tucson 85721

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Australian vs US body condition score

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Stage of lactation cycle	Days in milk	Rumen8 BCS (Aust) score 1-8	US BCS score 1-5
Calving	0	5.00	3.50
Early lactation	1-30	4.50	3.00
Peak milk & mating	31-100	4.25	2.75
Mid lactataion	101-200	4.50	3.00
Late lactation	201-300	4.75	3.25
At dry off	>300	5.00	3.50
During dry period	-60 to -1	5.00	3.50

The next few slides present data as they relate to the US body condition scoring system (scale 1-5)

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Condition score gain – lactating cows

MJ ME required to **GAIN** 0.5 BCS in lactating cows of different LW

Cow LW	BC score (1-5)		
	2.5	3.0	3.5
400	713	741	770
500	896	932	968
600	1079	1122	1165

Example:

- 500kg lactating cow
- Desired change: CS 3.0 to 3.5
- Time allowed 60 days (2 months)
  - 932 MJ ME / 60 days
    - = 16 MJ ME/day

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Condition score gain – lactating cows

Example:

- 500kg lactating vs dry cow
- Desired change – CS 2.75 to 3.25
- Time allowed 60 days

ME required: 25 vs 35 MJ ME/day

MJ ME required to **GAIN** 0.5 BCS in lactating and dry cows over different time periods

Live weight (kg)	Lactating cows			Dry cows		
	in 30 days	in 45 days	in 60 days	in 30 days	in 45 days	in 60 days
400	40	27	20	57	38	28
500	51	33	25	71	47	35
600	66	44	33	85	57	43

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Condition score loss

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- Condition loss occurs when the cow does not get sufficient energy in her diet and must draw on her body stores (fat and potentially muscle), resulting in loss of condition

Example:

- 500kg lactating cow in score 3.5 that loses 0.5 BCS – this mobilises 1494 MJ or the energy equivalent of **149 kg DM** @ 10 MJ ME/kg DM

MJ ME available for milk production from the **LOSS** of 0.5 BCS in Lactating cows

Cow LW (kg)	Starting PSU Condition Score		
	2.5	3	3.5
400	1359	1308	1258
500	1614	1554	1494
650	2208	2126	2045

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Condition score loss

- Condition loss occurs when the cow does not get sufficient energy in her diet and must draw on her body stores (fat and potentially muscle), resulting in loss of condition.

MJ ME per day available for milk production from the **LOSS** of 0.5 BCS in Lactating cows

Live weight (kg)	Lactating cows		
	in 30 days	in 45 days	in 60 days
400	34	23	17
500	43	28	21
600	51	34	26

Exercise 1-1

Exercise 1-1: Nutrient requirements (1/3)

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Worksheet 1: Daily energy, protein and fibre needs of a cow							
The Cow			**Her needs**				
Cow LW	A: [ ]	kg	*Energy for maintenance* — *Short Guide Table 1*		F: [ ]	MJ ME/d	
Daily milk yield — Volume	B: [ ]	litres	*Energy for Milk Production* — *Short Guide Table 3*	MJ/litre: [ ]	x	B: [ ]	= G: [ ] MJ/d
Fat	C: [ ]	%	*Energy for walking (select slope)* — *Short Guide Table 2*	[ ] MJ/km	x	H: [ ] km/day	= I: [ ] MJ/d
Protein	D: [ ]	%					
Prenancy stage — Number of days	E: [ ]		*Energy for pregnancy* — *Short Guide Table 4*	J: [ ] MJ/d		*Energy for body condition change* — *Short Guide Tables 5/6* — gain or loss?	K: [ ] MJ/d
			Her protein needs (g CP/kg DM) — *Short Guide Table 7*	[ ] L	g/kg DM	***Her fibre needs (NDF) (g/kg DM)*** — *Short Guide Table 7*	[ ] M g/kg DM
TOTAL ENERGY, PROTEIN & FIBRE REQUIREMENT			ME	*=F+G+I+J+K*	[ ]	MJ ME per day	
			CP	*=L*	[ ]	CP in diet g/kg DM	
			NDF	*=M*	[ ]	NDF in diet g/kg DM	

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Short Guide on ME, CP and NDF requirements - Rumen8 Tropics Course

All tables assumes mean diet ME of 10 MJ/kg DM

Table 1 - ME for Maintenance (MJ ME per day)

LW kg	10 L	15 L	20 L	25 L	Dry cows
400	54	55	55	56	50
450	59	60	60	61	54
500	63	64	65	65	59
550	68	69	69	70	63
600	72	73	73	74	67

Table 2 - ME for activity (MJ ME per km)

LW kg	Flat	Undulating	Steep
400	1.2	1.9	2.9
450	1.3	2.1	3.3
500	1.4	2.3	3.6
550	1.6	2.6	4.0
600	1.7	2.8	4.4

Table 3 - ME for milk production (MJ ME per litre)

Milk fat	Milk true protein %m/v					
%mv	3.0	3.2	3.4	3.6	3.8	4.0
3.0	4.83	4.90	4.99	5.08	5.16	5.25
3.5	5.17	5.25	5.34	5.42	5.51	5.59
4.0	5.51	5.60	5.68	5.76	5.85	5.93
4.5	5.85	5.94	6.02	6.11	6.20	6.28
5.0	6.19	6.28	6.36	6.45	6.54	6.62

Table 4 - ME for pregnancy (MJ ME per day for 500 kg cow)

Days pregnant	MJ required
0-90	<1
120	1
150	3
180	5
210	8
240	15
270	27
282 (full term)	34

Table 5 - ME required for 0.5 Condition Score GAIN (MJ ME per day)

LW	Lactating cows			Dry cows		
kg	30 days	45 days	60 days	30 days	45 days	60 days
400	40	27	20	57	38	28
450	46	30	23	64	43	32
500	51	33	25	71	47	35
550	59	39	29	78	52	39
600	66	44	33	85	57	43
Based on US 1-5 scale						

Table 6 - ME generated from 0.5 Condition Score LOSS (MJ ME per day)

LW	Lactating cows		
kg	30 days	45 days	60 days
400	34	23	17
450	39	26	19
500	43	28	21
550	47	31	24
600	51	34	26
Based on US 1-5 scale			

Table 7 - Requirements for protein (CP) and fibre (NDF)

Stage of lactation	CP g/kg DM	NDF g/kg DM
Early lactation	140-160	350-450
Mid lactation	130-150	400-500
Late lactation	120-130	450-550
Dry	120	500-600
Pre-calving transition	140	450-550
		peNDF minimum 200 g/kg DM

Exercise 1-1: Nutrient requirements (2/3)

- Assume mean diet ME 10 MJ/kg DM
- Cow LW 500 kg, milk yield 15 litres/day, fat 4.0%, protein 3.0%
- Mid lactation –30 days pregnant
- Body condition steady
- Grazing : total walking distance 3 km a day over flat terrain
- **Calculate daily nutrient requirements**
    - **Worksheet 1 & 'Short Guide'**

Exercise 1-1: Nutrient requirements (3/3)

- Same as before but now **GAIN** 0.5 BCS in 60 days

- Same as before but now **LOSE** 0.5 BCS in 60 days

Nutrient requirements - Protein

Factors affecting protein requirement

Protein requirement is affected by:

- mature cow size & stage of maturity (affects body composition)
- milk production & composition
- stage of pregnancy

Protein requirements

- Cows require metabolisable protein but here are some targets for **crude protein** content of the diet

- Figures at the higher end of these ranges are for:
  - Larger cows
  - Higher producers
  - Young cows, still growing

Stage of lactation	Crude protein requirements g/kg DM
Early lactation	140-160
Mid-lactation	130-150
Late lactation	120-130
Dry	120
Pre-calving transition	140

What about UDP / Bypass protein?

- Under some circumstances milk yield may increase in response to UDP supplements *(undegraded dietary protein)*
- But generally not required for cows producing <30 L per day

Nutrient requirements – Fibre

Neutral Detergent Fibre – the general rule

- Aim for NDF content of a lactating cow diet of 350 to 500 g/kg DM
  - Varies with stage of lactation and feeding system
- A diet with NDF 350 g/kg DM will lead to considerably higher feed intake compared to a diet with NDF 500 g/kg DM
  - We can estimate by how much…

Minimum NDF requirements for rumen health

Minimum requirement	g/kg DM
NDF	300-350
peNDF	200

Two fibre ‘rules of thumb’

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- **Setting lower and upper boundaries for NDF**
  - In TMR diets no less than 50% of all NDF in the diet should come from forage
  - Where concentrate is fed separately, 75% of all NDF in the diet should come from forage

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Key messages

- Basic "lookup tables" are available to provide information on the nutrient needs of the cow
- Estimates of requirements for energy and protein depend on
  - cow weight and condition
  - stage of lactation and pregnancy
  - diet quality
- Meeting fibre requirements is important, as is the form of fibre in the feed
- **Use of computer programs such as Rumen8!**

Q & A Discussion

Part 1F
Recap & closure for PART 1

Home work

- Participants to complete Worksheet 1 for a typical cow in a herd they are familiar with
- Needs Short Guide also
- To be presented at the start of Part 2

Worksheet 1: Daily energy, protein and fibre needs of a cow

The Cow			**Her needs**				
Cow LW	A	kg	*Energy for maintenance* *Short Guide Table 1*	F	MJ ME/d		
Daily milk yield Volume	B	litres	*Energy for Milk Production* *Short Guide Table 3*	MJ/litre	x	B	= G MJ/d
Fat	C	%	*Energy for walking (select slope)* *Short Guide Table 2*	MJ/km	x	H km/day	= I MJ/d
Protein	D	%					
Prenancy stage Number of days	E		*Energy for pregnancy* *Short Guide Table 4*	J MJ/d	*Energy for body condition change* *Short Guide Tables 5/6* gain or loss?	K MJ/d	
			Her protein needs (g CP/kg DM) *Short Guide Table 7*	L g/kg DM	***Her fibre needs (NDF) (g/kg DM)*** *Short Guide Table 7*	M g/kg DM	
TOTAL ENERGY, PROTEIN & FIBRE REQUIREMENT			ME *=F+G+I+J+K*		MJ ME per day		
			CP *=L*		CP in diet g/kg DM		
			NDF *=M*		NDF in diet g/kg DM		

Short Guide

Short Guide on ME, CP and NDF requirements - Rumen8 Tropics Course

All tables assumes mean diet ME of 10 MJ/kg DM

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Based on US 1-5 scale						

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LW	Lactating cows		
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Dry	120	500-600
Pre-calving transition	140	450-550
		peNDF minimum 200 g/kg DM

Dairy cattle nutrition in the tropics using Rumen8

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Part ONE finished

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