Animal nutrition training manual

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CHAPTER 1
COMPOSITION AND FUNCTION OF FEEDSTUFFS

Introduction: the Animal and its Food

Food consists of water and Dry Matter (DM). If the water content in food is 75%, the DM content is 25%. Although water is very important, the DM is crucial to the composition of a ration. More food is needed when it contains more water. The main components of a foods are:

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                                                                      | Degradable
                                                       | True         |
                                                       | Proteins     | Undegradable
     | Water                                      |
     |                     | N Compounds          | Non Proteins
     |                     | (CP)                      | (NPN)
     |                     |                           | Degradable
     |          | Organic  | Undesirable
     |          | Matter (OM) | Substances
Food |          |          |                           | Lipids (EE) +
     |          |          | N Free compounds          | Vit. A,D,E,K
     |          |          | Energy                    |              | Sugars,
     |          |                                      | Carbohydrate | Starches (NFE)
     | Dry      |                                                     |
     | Matter   | Vit. B,C                                            | Cellulose
     | (DM)     |                                                     | Lignin (CF)
                |
                |          | Major Elements
                |          | (Na,Ca,P,CL,K,S,Mg)
                | Inorganic |
                | Matter (IOM) | Undesirable substances
                | minerals/ash |
                           | Trace Elements
                           | (I,Mn,F,Co,B,Zn,Fe,Cu,M)
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1.1 Water

Water is vital to any animal. The bodies of young animals may consist up to 80% of their live weight. Older, and especially fat animals, have less water in their bodies (down to 50%).

Feeds can contain both high and low water percentages. Examples of feeds with high water contents are young grass (± 15% DM) and cabbage (< 10% DM). Hay and concentrates are feeds with low water contents (85-90% DM).

An animal obtains water from three sources: *drinking water*, *water present in food* and *metabolic water*. The latter is formed during metabolism by oxidation of hydrogen (H) containing organic nutrients. Water leaves the body with urine, faeces, milk, and as vapour via the lungs (respiration) and the skin (perspiration). There is no evidence that, under normal conditions, an excess of drinking water is harmful. If water is offered ad lib, animals normally drink what they require.

It is important to note that a lack of water in the diet results in a reduced appetite: a cow will eat less! This might affect DM intake which can have many consequences.

Dairy cattle require water for:

1. Chewing and swallowing (saliva)
2. Transport of nutrients around the body
3. Formation and maintenance of body tissues
4. Disposal of waste products
5. Regulation of the body temperature
6. Milk production

1.2 Dry Matter (DM)

All valuable feed substances are contained in the DM. If the DM% in a feed is known, it is possible to calculate how many kg DM an animal obtains from the feedstuff (and how many kg concentrate is needed as a supplement according to the norms for the production level).

The DM of a feedstuff can be divided into two groups:

- Organic Matter (OM)
- Inorganic Matter (IOM)

1.2.1 Organic Matter (OM)

The OM in a feedstuff consists of:

- Nitrogenous compounds = Crude Protein (CP) *
- Nitrogen-free compounds = Energy

* In reality, not all N compounds are CP, but it is convenient and almost universal for the N requirements of animals in the N status of foods to be stated in terms of protein. 30-40%

1.2.1.1 Crude Protein (CP)

Proteins are the *building blocks* in an animal. Protein is needed for growth, maintenance, reproduction and lactation. In general, every animal must have a constant supply of protein in order to remain healthy. A shortage will result in small calves at birth and/or slow-growing young stock (retarded growth). Other effects due to shortage of protein are:

1. Low milk production
2. Less protein in the milk
3. Loss of body weight in (early) lactation
4. Increased risk of infections and metabolic diseases
5. Low fertility (longer calving interval)

CP is made up of *true* protein (chains of amino-acids) and of inorganic nitrogen salts, amides and other substances. Amides can be seen as a substance which is to become *true* protein or as *broken-down true* proteins. In green, flushy products (e.g. young grass) a large part of the CP comes from amides. In full-grown vegetable products the amid content is normally low. The true protein can be divided into degradable and undegradable proteins.

Nitrogen in a feed, which does not come from protein, is named non-protein nitrogen (NPN), which are all degradable.

Ruminants, such as dairy cows, can very well utilize NPN (see Chapter 2). Hence, instead of feeding dairy cows expensive (true) protein, cheaper sources of nitrogen can be used as well. Urea which is relatively cheap chemical product, is such a non-protein nitrogen. However, certain precautionary rules must be observed when feeding non-protein nitrogen to dairy cows. It should be realized, that NPN (urea) can **only** be used in low level production systems with high amounts of poor quality roughage. In feeding high yielding dairy cows, this NPN does not play a significant role. In case the ration is deficient in energy, the cow will utilize part of the proteins as an energy resource, which may lead to protein deficiency.

1.2.1.2 Energy

The so-called *energy* contents of a feedstuff can be subdivided into two groups:

- Carbohydrates
- Lipids (fats)

Carbohydrates
Carbohydrates are sugars and starches derived from cereals, tubers, roots, and other substances such as cellulose and lignin from plant cell walls, vessels and woody tissues. Carbohydrates do mainly provide energy for maintenance and production. A surplus of energy is stored as body fat.

A part of the carbohydrates is *crude fibre* (CF), the remaining is *nitrogen-free extract* (NFE). The latter consists of sugars, starches and sugar-like substances. Sugars and starches are much easier to digest than CF. CF is very important for the functioning of the rumen and for production of milk rich in butterfat. Food for dairy cows should therefore contain a good quantity of CF. In total, the ration should contain at least 30 % roughage (on DM base).

Lipids (Fats) or Ether Extract (EE)
Lipids also provide energy. In fact, lipids provide much more energy than the same amount of carbohydrates (multiplication factor: 2.25). The fat soluble vitamins A, D, E and K are found in the lipid fraction. Because of the vitamins, some fat must be present in the feed. However, too much in the ration lowers feed intake of the ruminant and disturbs functioning of the rumen.

Roughage have a low fat content. Feedstuffs derived from oilseeds (e.g. soya, cotton) have a relatively high fat content.

1.2.2 Inorganic Matter (IOM)

IOM is also called ash. IOM content is determined by burning samples until no carbon is left. A high level of ash in a sample often indicates contamination with soil. For example, over 10% ash in roughage (silage) or concentrates indicates soil contamination or adulteration with e.g. chaff.

Ash contains the minerals. Minerals are very important for building-up the body as in the bones and teeth. Minerals are needed as a part in proteins to make-up the soft tissues of the body. Further more, numerous enzyme systems and osmotic regulation of the body require minerals. Consequences of a shortage of minerals can be:

1. Low fertility
2. Poor growth
3. Diseases
4. Deformation of the skeleton
5. Low production

Generally speaking it is advisable to provide livestock with ad lib mineral blocks and/or with a mineral mixture included in concentrates. Another possibility is to correct mineral deficiencies in the soil by application of appropriate fertilizers.
Minerals are divided in *major* and *trace* elements. The only difference is that animals need large(r) quantities of the major-elements.

1.3 Minerals

The important minerals in dairy cattle feeding are divided into two groups:

- Major Minerals
- Trace Minerals

1.3.1 Major Minerals

Calcium (Ca)
Ca is the most abundant mineral element in the body and a very important constituent of the skeleton and teeth, in which 99 % of the total body Ca is found. Substantial amounts of Ca are released in the milk.
Deficiency symptoms:
- rickets (misshapen bones, lameness) especially in calves
- milk fever (hypocalcaemia)

Sources: bonemeal, shell meal, lime, meat meal, fish meal, milk, legumes, pulses, dicalcium-phosphate.
Ca utilization in the body is strongly associated with phosphorus (P) and vitamin D. The required Ca : P ratio for dairy cattle is in general 1½-2 : 1.

Phosphorus (P)
P is used in bone formation, in close association with Ca and vit.D. In addition, P has more known functions in the animal body than any other mineral element. Deficiency symptoms are mainly related to P deficiency in soils and is the most important deficiency in grazing animals.
Deficiency symptoms:
- rickets
- chewing wood, bones, rags etc.
- poor fertility
- lower milk yield

Sources: cereal grains, bonemeal, dicalcium P, milk, and fish meal.
Note: *di-CaP can **not** be distinguished from mono-CaP by the "naked eye". However mono-CaP cannot be absorbed/utilized by the animal.*

Potassium (K)
K is very important for osmotic regulation of the body fluids and regulation of the acid-base balance in the rumen, along with NaCl. Deficiency is very rare, although excess K may interfere with the absorption of magnesium (Mg), leading to hypomagnesia (grass staggers, grass tetany). K-contents in plants is generally rather high.

Sodium Chloride (NaCl)
NaCl is also known as common salt or kitchen salt. Functions in association with K in the acid-base balance (rumen pH) and the osmotic regulation of body fluids. This is very important in the warmer climates (sweating). Deficiencies are usually indicated by a general poor performance (poor growth, infertility). Most feedstuffs, especially plant originated food, have a comparatively low NaCl contents (except meatmeal and foodstuffs of marine origin). The main source of NaCl is common salt which should be provided ad lib., either as a "lick" or in a special water trough with a 2-2.5 % salt contents (2-2.5 kg of salt in 100 litre of water).

Sulphur (S)
S occurs mainly in the proteins in the body. Deficiency indicates basically a protein deficiency in the ration. Extra sources of S may have to be included in diets with substantial amounts of NPN (urea). Potential S sources are: protein rich sources (soya cake, cotton seed cake) or sodium sulphate.

Magnesium (Mg)
Mg is closely associated with Ca and P. 70 % of Mg is found in skeleton, the remainder being distributed in soft tissues and body fluids. Deficiency is not uncommon in milk fed calves between 50-70 days of age. Symptoms are poor bone formation (calves) and hypomagnesemia (grass tetany). The absorption of Mg may be inhibited by high levels of K from manured pasture grass. Sources are: wheatbran, legumes, plant protein cakes like cottonseed cakes (not suitable for calves; gossypol) and soya cakes.

1.3.2 Trace Minerals

Iron (Fe)
More than 90 % of the Fe in the body is combined with proteins, mainly haemoglobin. Deficiency is indicated by anaemia, especially in young calves which are only fed on milk. Deficiency is not common in adult cattle, as Fe is widely distributed in the feedstuffs (except milk). Good sources are: green leaves, legumes, seed coats and meat, blood and fish meals.

Copper (Cu)
Cu is necessary for haemoglobin formation and pigmentation. Deficiencies are indicated by anaemia, dull coat colour (black hairs become brownish), infertility and scouring. Cu is widely distributed in feedstuffs and under normal conditions the diet of dairy cattle contains adequate amounts of Cu. Seeds and seed by products are normally rich in Cu, provided that there is no Cu deficiency in the soil.

Cobalt (Co)
Co is important for the functioning of the rumen micro organisms (RMO's) in association with vitamin B12, which contains Co. Symptoms of deficiency are emaciation, anaemia, pining. Most foods contain traces of Co and normally deficiencies do not occur.

Iodine (I)
I plays an important role in the functioning of the thyroid gland. The main indication of deficiency is an enlargement of the thyroid gland, known as "*endemic goitre*" (big neck). The deficiency may result in breeding problems and birth of hairless, weak or dead calves. Feed of the Brassica family (kale, rape, rape seed, cabbage), but also soya beans, peas and ground nuts may contain goitrogenic substances causing goitre if given in large amounts. I occurs in traces in most foods. In areas where goitre is endemic (inland), precautions can be taken by supplementing the diet with I, usually in the form of iodized salt.

Manganese (Mn)
Mn is an enzyme activator. Very little amounts are required. As Mn is widely distributed in feedstuffs (especially in wheatbran, ricebran and seeds), usually no problems are encountered.

1.4 Vitamins

Vitamins are indispensable, but the animals need them only in very small quantities. The most important vitamins are:

- Water soluble vitamins
- Fat soluble vitamins

1.4.1 Water Soluble Vitamins

Vitamin B (complex)
This group of vitamins is produced by the animals themselves in the rumen and a shortage is not likely in ruminants, except when the diet is short of cobalt. Bran, milk and brewers grain are rich sources of vitamin B for cattle.

Vitamin C
All farm animals can synthesize vitamin C and will not experience a shortage. Green leafy vegetables, citrus and potatoes are sources rich in vitamin C.

1.4.2 Fat Soluble Vitamins

Vitamin A
A shortage of vitamin A causes a dry skin, infections of the skin and eyes, the digestive tract (diarrhoea) and the genitals (infertility). Green feedstuffs, carrots and yellow maize contain high amounts of vitamin A. Indoor cattle systems, without green feedstuffs may require supplementation, especially calves, usually in the form of vitamin AD 3.

Vitamin D
Vitamin D assists in the depositing of Ca and P (skeleton) and produced by the action of sunlight on the skin. So outdoor systems will not experience deficiencies. Indoor animals (calves!) may suffer deficiencies (symptoms: rickets, see Ca and P) and require supplementation (vit AD 3). Sun dried feedstuffs (hay, straw) are good sources of vitamin D.

Vitamin E
Vitamin E is considered important to fertility in association with Selenium (cows) and muscle development (calves). Green foods and cereal grains are important sources.

Vitamin K
Vitamin K assists in the blood clotting. Green fodders are rich in vitamin K, but the ruminants synthesize vitamin K (RMO's) and deficiencies are normally not experienced.

1.5 Undesirable Substances

Unfortunately, some feedstuffs may contain also some undesirable substances:

- **Natural substances**
  such as gossypol in cotton seed cake, prussic acid in sorghum, goitrogenic substances in the Brassica family, silicium in straw, aflatoxin in groundnut products, oestrogenic substances in some legumes, tannin and mimosine.

- **Contamination due to improper handling**
  for example soil in silage, dirt in milling products, and mould in hay.

- **Adulteration**
  contamination with chaff, hulls, sawdust, sand, etc.

CHAPTER 2
THE DIGESTIVE SYSTEM

Introduction

Cows are *ruminants*, as are goats, buffaloes, giraffes, camels and antelopes. Ruminants have the ability to digest large amounts of roughage containing high amounts of (crude) fibre and cell wall materials (cellulose, lignin). Their alimentary tract is specially adapted, and they have the following main characteristics:

- Absence of front teeth (incisors) in upper jaw, which facilitates rumination and/or mastication of fibrous material.
- A complex stomach specially "designed" to break-down large amounts of roughage (rumen reticulum as a microbial "fermentation barrel").

Digestion means the breaking-down of different food components into simpler compounds. Hence, they can pass through the mucous membrane (wall) of the gastro-intestinal tract into blood and lymph (absorption) and be transported to those places in the body where needed. In cattle, the process of digestion can be divided into 3 groups:

1. Mechanical digestion, to reduce the size of food-particles by chewing, mastication (rumination) and muscular contractions of the gastro intestinal tract, especially the rumen reticulum and omasum.
2. Microbial digestion, brought about by *rumen micro organisms* (RMO's), consisting of: degradation + synthesis in rumen/reticulum
3. Chemical digestion through enzymes, secreted by the animal in the various digestive juices in the abomasum and intestines.

2.1 Process of Digestion in Cattle

2.1.1 The Mouth

The mouth is used for:

- Eating/cutting, chewing and mixing food with saliva and formation of boluses/cuds and swallowing.
- Rumination/mastication

The saliva plays a very important role in digestion and is very rich in the following minerals:

- NaHCO3 (sodiumbicarbonade), K and P.
  These are the so called *base minerals*, which are recycled through the blood. They provide the buffering-capacity to keep pH in the rumen at a desired level (control acidity).

- Ca, S, Mg and urea ([NH2]2CO).

The saliva also is rich in agents that prevent the formation of foam in the rumen (bloat). The amount of saliva produced can reach up to 150 litres per day, partly depending on the type of food. On average a cow needs per day about 8 hours for eating and 8 hours (max. 10-11 hours) for rumination! Each bolus of food is normally ruminated for about 40-50 times (sign of health).

2.1.2 Stomach Complex

The stomach of a cow is divided into 4 compartments, as shown in figure 2.1:

1.	Rumen	\	Pre-stomachs
2.	Reticulum/honeycomb	→	with *rumen micro organisms*
3.	Omasum	/	(RMO's)
4.	Abomasum	→	True Stomach Enzymes

The abomasum (true stomach) is similar to the stomach of non-ruminants (mono-gastrics). The other 3 pre-stomachs are specific for ruminants.

Just after birth, the pre-stomachs of a calf are still relatively undeveloped. The milk, which a calf drinks, is channelled directly through a *groove* (tube-like-fold) to the omasum and abomasum. However, the pre-stomachs develop rapidly if stimulated by feeding good quality roughage and concentrates. This should start at about one week after the birth. In adult cows the volume of the three pre-stomachs is about 14 times larger than the abomasum. A well developed rumen has a volume of 100-150 litres. The four stomachs together fill about 3/4 of the abdominal cavity. A well developed rumen is essential for the intake of high amounts of roughage and concentrates, resulting in a high (milk) production. During calf rearing and young stock rearing, special attention should be paid to the development of the rumen. The size of the rumen is a main factor in the potential intake of DM, and thus production.

Figure 2.1: the Structure of the Stomach of Cattle

2.1.2.1 Rumen and Pre-stomachs

The rumen is basically a large barrel for digestion/fermentation of food by *rumen micro organisms* (micro bacterial digestion). These RMO's are mainly bacteria and protozoa.

Rumen Contents
The rumen contents is normally made up of three layers:

1. A top layer of methane gas (CH_4) and carbondioxide (CO_2), produced by RMO's as by-products from breaking-down (fermentation) carbohydrates. The gas is partly absorbed directly through the rumen wall into the blood and expelled through the lungs by breathing and partly expelled through eruption/burping. Failure to eruct causes bloat.

2. A middle layer of recently ingested coarse materials (solid mass). In this layer, fermentation takes place. Particles size is reduced through mechanical action (contraction of the rumen) and microbial action and fibres become water soaked. Absence of this layer as a result of high quality energy diets supplied by concentrates (low roughage intake) causes (severe) problems. For a proper functioning the rumen, a minimum amount of fibre is required. As rule of thumb, a minimum of 30 % of the total DM ration should be supplied by roughage. In a healthy cow it is possible to feel the contractions by pushing your fist *deeply* into the rumen. The rumen contracts and expands about 10-12 times per 5 minutes (sign of health). From this layer, food is ruminated 40-50 times per cud and swallowed again.

3. A bottom layer consisting of liquid mass

Rumen Climate and Rumen Micro Organisms (RMO's)
RMO's can either be bacteria, the active digesters and fermenters (16,000 x 10-6 in number), or protozoa, of which the role is less clear (34 x 10-6 in number). The total mass of RMO's (microbes) in the rumen is over 5 kg, "producing" several 100's of grams microbial protein per day and fermenting carbohydrates into *volatile fatty acids* (VFA's).

In an adult cow, the size of rumen and reticulum is 60-150 litres. The rumen has a specific *climate*:

- Basically anaerobic (no oxygen). Small amounts of oxygen enter the rumen with food and are quickly oxidized.

- A pH of 6-7. This is the ideal climate for microbial growth and activities to break-down roughage. Concentrate diets, low fibre and high in energy, may cause the rumen pH to decrease to levels below 6. This has in general a negative effect (lower butterfat percentage, depressed appetite, metabolic disorders, and possibly death). A higher pH (>7) may be caused by urea toxicity (alkalosis) and possibly be followed by death.
  Note: *monogastrics have a stomach pH 2.*

Rumen Fermentation
Rumen fermentation consists of two processes:

A.	Microbial degradation of food components, mainly carbohydrates and proteins. Food enters the rumen partly in a degradable form, and partly in an undegradable form. If the undegradable food particles are sufficiently reduced in size, the particles move to the abomasum and small intestines for digestion and absorption.	
B.	Synthesis of organic macromolecules into microbial biomass, mainly proteins, nucleic acids and lipids. (Tropical) forages in a late stage of maturity (hay, straw) usually have a high fibre contents and can be highly lignified and usually have a low protein contents. Utilization of energy from such roughage increases heat production, lowering the feed intake, which was probably already low due to the slow rates of degradation and slow rate of passage of food (full stomach, thus feeling less hungry).	

2.1.3 Abomasum and Small Intestines

In the abomasum and small intestines the "normal" chemical digestion (enzymes) takes place of the food as in monogastric animals. This digestion does not affect the management of ruminant nutrition and is consequently not further discussed in this paper.

2.2 Digestion of Food Components in Rumen

2.2.1 Fermentation of Carbohydrates

All carbohydrates entering the rumen are "attacked" by RMO's, except lignin. Generally, 90% of the carbohydrates are broken-down (degraded, fermented, digested) into three types of Volatile Fatty Acids (VFA's). In a ration with mainly roughage, VFA's are normally proportioned as follows:

-	Acetic acid (acetate)	65-70%
-	Propionic acid (propionate)	20-25%
-	Butyric acid (butyrate)	10%

Also carbondioxide (CO_2) and methane (CH_4) are released in the process. Quite some body heat is produced from energy required to break-down carbohydrates. Poorer quality roughage require more time and energy from RMO's. This slows down digestion of roughage and increases body heat production. Ensuing, this leads to a lower food intake due to lower turn-over rates (passage rates of food in the rumen). Increase in heat production by the body may also depress appetite, especially in warm climates/seasons and/or during hotter parts of the day. The production of body heat and gas is at its peak immediately after a meal. Gas production can reach over 30 litres of gas per hour. Regular feeding or continuous access to food will reduce the gas- and heat production peaks, while night feeding of roughage will increase appetite (DMI). The latter should especially be considered for the warmer climates and seasons.

The amount of VFA's produced can be as high as 4 kg/cow/day. Most of the acids are directly absorbed into the bloodstream through the walls of the pre-stomachs (mainly rumen). Some VFA's enter into the abomasum and small intestines and some VFA's are used by the RMO's for the development of their own microbial tissues.

In rations with substantial amounts of roughage, acetic acid will exceed the amount of propionic acid. Acetic acid is formed mainly from cellulose and has a very positive effect on the butterfat contents of milk. A sufficient amount of cellulose (fibre) in a ration is also essential for a proper functioning of the rumen and to keep the desired optimum range of the rumen pH level between 6-7.

However, propionic acid production may exceed acetic acid production in diets containing high levels (over 70% of the total ration DM) of energy rich concentrates. Starches and sugars are very quickly fermented into propionic acid. This results in lowering the rumen pH level. Also less saliva will be produced and consequently less base-minerals, with an acid buffering capacity, will enter the rumen. The consequences depend on how much the rumen pH will be lowered:

- At pH 5, the appetite will decrease as the first RMO's get killed. The lower amount of acetic acid and higher amount of propionic acid will results in a lower butterfat content in the milk: the so called *low butterfat-syndrome*

- At pH levels below 4½, the animal may suffer from acidosis. This can lead to laminitis (hoof problems) and ketosis (fat cow syndrome). The normal RMO's in the rumen are getting destroyed, as the more acid loving lacto-bacilli (lacto-acid) will start to prevail. Symptoms indicating acidosis are: panting, distress, diarrhoea and anorexia. In prolonged cases, the rumen wall lining may be affected, destroyed and shed.

- At pH level below 3½, the cow may experience shock and die of toxaemia.

In order to prevent the diseases and to keep the rumen functioning at an optimum, with a sufficient level of butterfat in the milk, it is advised to feed a maximum of 70% DM concentrates, and a minimum of 30% DM roughage.

Note: *Monogastric animals that can eat large quantities of roughage, such as horses, donkeys, rabbits and pigs to a certain extend, have bacterial protozoal fermentation of carbohydrates (fibre, cellulose etc.) in specific parts of the hindgut (intestines after the stomach), like the caecum and/or colon. These are generally less efficient than the rumen.*

2.2.2 Digestion of Lipids/Fats (Ether Extract)

Ruminants have evolved as *plant-eaters* and the rumen is not adapted to diets that contain a high amount of lipids/fats. The capacity of RMO's to digest lipids/fats is strictly limited. Fat/lipid contents of ruminant diets is normally low (< 50 gr/kg DM). If fat/lipid content is increased above 100 gr/kg DM (= 10%) the RMO's reduce their activity. This leads to:

-	Decreased fermentation of carbohydrates
-	Reduced intake of DM

Stearic acid is the predominant fatty acid of ruminant fat deposits due to RMO's activities. Recent efforts to include undegradable *by-pass* fat in concentrates to add cheap energy to rations have not (yet) produced any significant results.

Deficiencies of fat are not likely to occur, since the available fatty acids are efficiently used by the metabolic system of the animals.

2.2.3 Protein Degradation and Synthesis

2.2.3.1 True Proteins

Most of the true proteins entering the rumen are degraded by RMO's into amino-acids. Subsequently, ammonia (NH_3) is produced (degradation). RMO's can utilize both amino-acids and NH_3 to be synthesized into proteins. These are used as building stones for their own new bodies: the microbial protein! The ruminant does not depend on the protein quality of the diets for its survival (maintenance), although the *quality* of proteins becomes an important factor for good milk production. When RMO's die, they will be *washed* into the abomasum and small intestines, where the microbial protein is digested in the *normal* way (chemical digestion) and absorbed.

With most diets, majority of protein reaching the small intestine of a cow will be microbial protein of reasonable constant composition. Not all the true protein in food is degradable into ammonia. Some of the undegradable true proteins will escape the rumen degradation and will be digested in the small intestines. In highly productive dairy this is essential, since the capacity of the RMO's is too low to synthesize all the protein needed at the high milk production levels. This undegradable protein sometimes is, misleadingly, called *by pass* protein. This protein does not *by pass* the rumen, and is therefore not degraded by RMO's.

Proteins of different feedstuffs have a different percentage of *by pass* protein. The rumen degradability of some proteins from different foods varies between 40-90%. E.g. for young grass and good grass silage, degradability is indicated at 85%, while degradability of protein from meat/bonemeal and white fish meal is respectively 50% and 40%. Degradability of a food is however influenced by particle size and feed intake level (speed at passage through the rumen). A separate list indicating the degradability of certain foods is given in Appendix 1.

If a diet is deficient in protein (negative N balance), or if protein is largely undegradable and not available to RMO's in the rumen, concentration of ammonia will be (too) low. Growth of RMO's will slow down. This results in a longer fermentation time in the rumen and consequently in a lower food intake and loss of bodyweight! (slower digestion, food stays longer in the rumen, cow feels less hungry, "dying with full stomach"). The minimum level of required ammonia for a proper functioning of RMO's in the rumen is reached when a diet is fed with a minimum of 7% CP (= 4.55% DCP)! A protein or N deficient diet may lead to cannibalism among the RMO's.

On the other hand, if protein degradation proceeds more rapidly than the synthesis of microbial protein, ammonia will accumulate in the rumen liquid. The optimum concentration level will be exceeded. This optimum level is reached at a CP level in the diet of 13% (= 8½% DCP). Above this level, bacteria can not utilize all the NH_3. If the required level of CP in the diet is higher for a certain production level, the protein should be made available to the animal in the form of **undegradable** protein. Otherwise, the excess ammonia in the rumen will be absorbed by the rumen wall, taken into the blood, carried to the liver and converted into urea. Some of this urea may return to the rumen via the saliva and/or directly through the rumen wall. However, the majority will be excreted through kidneys in the urine, and thus wasted! An overall diagram of protein digestion in cattle is presented in Figure 2.2.

Figure 2.2: Digestion and Metabolism of N Compounds in the Rumen

2.2.3.2 Utilization of NPN (Non Protein Nitrogen Compounds)

The ammonia pool in the rumen is not supplied only by degradation of true protein. As much as 30% of nitrogen in ruminant foods may be in the form of simple organic compounds, such as amino-acids and/or inorganic compounds.

2.2.3.3 Urea $(NH_2)_2CO$ as a Protein Replacer

If food is short in protein, urea can be used as a supplement in order to improve the nitrogen balance of the animal. Urea is rapidly converted into ammonia in the rumen by the action of water:

$(NH_2)_2CO + H_2O$	--->	$2NH_3 + CO_2$
urea		ammonia

However, one has to be careful with urea as a supplement. High amounts of ammonia in the rumen and in the blood may lead to toxicity and possibly death (urea toxicity). In practice urea is only supplemented to rations with a rather low energy and protein value (poor roughage quality). The supplementation of urea to dairy with a high production potential is not recommended, as results have been disappointing.

This training course supports management of intensive/high dairy production systems with feeding rather high amounts of concentrates. These concentrates should contain sufficient amounts of proteins to meet the need of degradable proteins. Therefore, the subject is not further elaborated upon, as urea does not play a role in these systems. Treatment of straw with urea may offer some scope for certain production systems.

2.3 Practical Implications for Ruminant Management

The rumen plays a very important and specific role in the digestion of food by dairy. In order to exploit the high (genetic) potential of a cow to an economic maximum, a manager has to consider some important aspects in the feeding. In fact, one must know exactly how to manage and manipulate the RMO's in the rumen. The farm manager thus has to be a *Rumen Management Officer*.
Some aspects to consider in *feeding management* are:

A. Composition of the ration.
   It is seen, that the RMO's play a very important role in the digestion of food. RMO's have to adopt themselves to certain rumen climates as created by the different types of food given to them. Changes in the diet and in the composition of the ration will disturb and/or change the rumen climate to which the RMO's have adopted themselves. Therefore such changes should be as much as possible limited and only introduced **very gradually**.

B. Frequent feeding will reduce the peaks in heat-and gas production.
   This peaks may result in lower food intake. For a high milk production a high food intake is essential and it is therefore advisable to allow the dairy cattle to have continuous access (24 hours per day) to food and water. During warmer seasons roughage should be offered during the cooler nights. If outside feeding is practised (in yards) during the hotter parts of the day (between 10 am and 4.30 pm) it is advised to provide shade over the feeding place and feed-trough. Shade protects animals from direct sunlight and also may create some extra natural ventilation, reducing the heat load.

C. Sufficient (ad lib) amounts of water should be available to support food intake. Water plays an important role in the digestion of food (saliva).

D. Sufficient minerals P, Ca and Na have to be offered.
   Those are the most important minerals excreted in the saliva to regulate the pH level of the rumen (acid-buffering capacity) to create an optimum environment for the RMO's.

E. A minimum amount of (good quality) roughage has to be offered.
A minimum 30 % of the total DM allows the rumen to function properly. This will avoid rumen and metabolic disorders due to a lowered rumen pH and guarantees a high butterfat content in the milk. If the available roughage is ground finely or chopped less than 1 cm, arising problems may be similar to lack of fibre structure. One has to keep in mind that the rumen (ruminant) evolved in order to digest large amounts of roughage (nature!).

F. Poor quality roughage with low digestibility, such as straw, stover, chaff and mature stalky hay takes a longer time to be digested in the rumen and increase the heat-load in the animal (body-heat). This reduces the capacity to eat large amounts of roughage and either results in a higher demand for concentrates. This is probably more expensive, or reduces production.

G. The total diet may not contain more than 10% fats/lipids (EE).

H. For the proper functioning of the RMO's, a minimum CP content of 7% is required in the diet (survival diet). The degradable part of the CP can be utilized up to a maximum level of 13% CP. Protein requirements over 13% CP (protein requirements) are to be fed as undegradable protein. The degradable proteins with a CP contents of over 13% will be excreted as urea in the urine, and therefore lost.

I. NPN supplement (urea) for (high yielding) dairy is usually not suitable as the NPN will be quickly degraded and probably excreted (see previous point).

J. Signs of health are:
- a good appetite
- a rumination of 40-50 times per bolus, and
- rumen contractions of 10-12 times per 5 minutes

K. High standards of feeding are required for calves and young stock. The rumen need a good development to ensure maximum intake of DM in order to reach a high production level (a cow *only* converts!).

CHAPTER 3
FEED EVALUATION AND EXPRESSION OF VALUE

Introduction

Expression of values are used to show the nutrient requirements and nutrient values in feedstuffs. The total value of a feedstuff in practical nutrition depends on the following factors:

1. Energy content → carbohydrates, fats, proteins & digestibility
2. Protein content → including NPN and aspects of degradability
3. Nutrient density (digestibility) and structure value
4. Digestibility
5. Vitamin/mineral contents
6. Special aspects → like keeping quality, taste, toxins, influence on milk colour/taste, availability, handling etc.
7. Physical aspects
8. Price

The expression of *feed value for dairy cattle* strictly speaking, however, is a measurement for energy content unit and the amount of protein, in Poland respectively in the values *FUM units* and *gram DCP per kg (or kg DM) product* *.

* Note: *Recently, the Polish system for animal nutrition has been adjusted. The so-called "Jednostka Paszowa Produkcji Mleka" (JPM) is used for defining energy requirements and energy availabilities. JPM is based on the Nett Energy system and as such comparable with the FUM unit utilized in this course book.*

For more information, it is referred to the book on animal nutrition (Polish edition) "_ywienie Prze_uwaczy", published by Omnitech Press - Warsaw.

As mentioned in Chapter 1, the feed value (nutritive value) of food is contained in DM, the remainder of food being water. The DM is expressed as a percentage (%) or as gram per kg of food. For instance, the DM of grass is 15% equals 150 gram DM/kg grass. DM is very important to an animal as it is used to measure hunger or appetite (the amount of food an animal can eat per day). The daily amount of DM eaten per day is called *Dry Matter Intake* (DMI). The total composition of the daily ration should include all nutrients required necessary for *maintenance* and *production* purposes within the quantity of DM.

Throughout this paper, calculations will use expression of feed values per kg DM of a feedstuff. If one feedstuff is compared with another the same system should be applied, otherwise the results will be distorted!

3.1 Energy Content

One of the main functions of a dairy ration is to provide energy to an animal. The total energy of food coming free during combustion is called **Gross Energy**. Only a fraction is used for *maintenance (including some milk production)* and *production*. Utilization is reduced by losses of defecation, urination, methane gasses in the rumen and heat.

The term "energy" includes the actual physical energy an animal needs, the heat to maintain its body temperature, the energy required for production and the nutrients for laying down its own energy reserve. The constituents that provide energy are the carbohydrates, fats and possible proteins! If there is not enough energy from carbohydrates and fats in the food to meet its daily requirements, part of the available proteins is converted into energy-use.

Not all energy value fed can be utilized for production and maintenance. The portion available for maintenance and production is called **Nett Energy (NE)**, usually expressed in Joules (KJ = 1,000 J, MJ = 1,000,000 J).

Figure 3.1 shows that the energy value is most accurate with **Nett Energy**. This is the energy effectively used by an animal and defined for its utilization purpose. In order to compare energy values amongst different foodstuffs, it is desirable to express the energy value in one kg (or 1,000 gram) DM (of kg) of one of the foodstuffs involved. The NE system requires precise knowledge of bodyweight, quality and quantity of feedstuffs fed and eaten by the animals.

Values are expressed both on *wet basis* and *DM basis*. Care should be taken. For the purpose of calculation we use the values based on DM.

In Poland, **energy requirements** are expressed in **FUM** (Feed Units Milk)* per day:

FUM for cows is a figure indicating the amount of barley in grams which gives as much Nett Energy for milk production as 1 kg foodstuff.

* See note on JPM

As a rough rule

A 600 kg cow producing 15 litre milk per day (4% fat) requires 11,913 FUM, for	
- **maintenance**	**→ 5013 FUM**
- **production of every 1 kg milk 460 FUM**	**→ 15 * 460 = 6900 FUM**

3.1.1 Major Energy Systems

The major energy systems in practical use for dairy production are:

1. Starch Equivalent (SE)
2. Total Digestible Nutrients (TDN)
3. Metabolizable Energy (ME)
4. Nett Energy (NE)

Energy utilization of food (DM) **Expression of Energy Value**

GROSS ENERGY (GE) 100 %

LOSSES:
→ faecal energy 20-70 % of GE
(big variation)

FOOD FACTOR

DIGESTIBLE ENERGY (DE) → **TDN**

→ urine + methane → 18 % of DE (fairly constant)

METABOLIZABLE ENERGY → **ME**

ANIMAL FACTOR

→ heat-increment 40-80 % of ME
(big variation)

NETT ENERGY → **SE** (starch equivalent)

→ Nett Energy Maintenance NEM
Nett Energy Growth NEG
Nett Energy Lactation NEL

Figure 3.1: Energy Utilization of Food

3.1.1.1 Starch Equivalent (SE)

This is an earlier system of NE utilization. The system is based on production of body fat and not on milk production. The conversion efficiency of energy varies for different feeding purposes (maintenance, growth, lactation). Therefore the SE system is outdated and not commonly used any more in dairy production.

3.1.1.2 Total Digestible Nutrients (TDN)

This system is based on an estimation of digestible energy (DE) with correction for losses in urine and methane. Calculated of TDN is as follows (in %):

TDN %	= % DCP + % DCF + % DNFE + 2,25 * % DCEE		
with	DCP	digestible crude protein	
		DCF	digestible crude fibre
		DNFE	digestible nitrogen-free energy
		DCEE	digestible crude ether extract

Fat has a high energy value!
The fat energy value is obtained by multiplying fat content with factor 2.25.

The TDN system is simple and practical. It works satisfactory under systems where nutrition factors are rather variable (amount, type and quality of food), body weights are roughly estimated, and milk production is below the genetic potential due to management, climate and/or infrastructure (health, breeding services). The TDN system fails to consider variation in efficiency amongst feedstuffs with which TDN is utilized (from ME to NE). It tends to over-estimate the value of low quality roughage. The TDN system is widely used in the world, special in developing countries. It is an excellent tool for providing guidelines for a sound animal nutrition policy for dairy farmers under given circumstances.

3.1.1.3 Metabolizable Energy (ME)

In some European countries, this system is replacing the previous SE system. The ME system is more accurate, but is only useful in situations where animals are producing at a maximum of their (genetic) capabilities and where all other aspects of nutrition are done very precisely with constant qualities and continuity. To determine food value is rather expensive and time consuming. Therefore, ME is frequently calculated as ME = 0.82 * DE (the factor for energy loss in urine and methane is considered to be fairly constant at 18% of DE).

3.1.1.4 Nett Energy (NE)

This system is an improvement version of the SE system. Different efficiencies for energy utilization of different purposes (maintenance, growth, lactation) are recognized. The NE system requires actual measurement per feedstuff, which is complicated and costly. The variation of 40-80% energy loss from ME into NE due to heat-increment prevents that NE values can be abstracted from TDN or ME. The NE system is very accurate and valuable in production systems where all other factors of nutrition are accurately controlled. In many dairy producing countries, Nett Energy values are adopted to units of lactation energy: USA (NE lactation), China (NND: dairy energy unit), Holland and Poland (FUM).

3.2 Protein Content

The value of protein is usually expressed as crude protein (CP) or digestible crude protein (DCP). The DCP and/or CP values are indicated:

Sometimes as	→ %/gram CP/DCP per kg food on a wet/fresh basis,
or sometimes as	→ the same values on a DM basis!

Care should be taken! In this paper calculations will only use the system of gram DCP per kg DM of a food. If one feed is compared with another the same system should be applied, otherwise the results will be distorted!

Note: *the Polish system is using the term Bia_ko Trawione w Jelicie (BTJ), which means intestinal digestible protein. For more information, it is referred to the book "_ywienie Prze_uwaczy", Omnitech Press - Warsaw.*

As a rough rule

A 600 kg cow producing 15 litre milk per day (4% fat) requires in total 1335 gr DCP, for

- **maintenance** **→ 390 gr**
- **production of every 1 kg milk → 63 gr** **→ 15 * 63 = 945 gr**

The CP value is measured by determining the amount of N in a foodstuff. As all proteins contain 16% N, the CP content is determined by: **100/16 = 6.25 * N**. For good milk production a certain amount of undegradable protein is required. See appendix 1 for the degradability of the proteins in various feedstuffs. Urea is the main NPN compound used in animal nutrition. Its CP content is very high. Urea contains 46.6% N (= 466 gr/kg), which is equivalent to a CP content of 466 gr * 6.25 = 2,913 gr/kg (all degradable).

Generally speaking, DCP values are estimated to be 60-70% of the CP values. However, variations are considerable and this estimation might not be accurate enough. DCP values vary from food to food (and from quality to quality) and should be separately determined by digestibility trials. Evaluation of large food numbers to determine DCP by digestibility trials as routine is impracticable. In **concentrates** the DCP is usually calculated with the CP value multiplied by the available digestibility coefficients. In **roughage** the approach is different. Due to greater variability and regression, equations are used to calculate DCP from CP.

A typical equation widely used for grass, hay and silage is:

DCP (gr/kg DM) = CP (gr/kg DM) * 0.91 - 36.7

The use of this equation may lead to the allocation of negative DCP values in certain low CP roughage, such as cereal straws (> 40 gr CP/kg DM).

Some examples of digestibility of CP for certain feedstuffs are:

-	Good hay/silage (young material)	60% - 70%
-	Average hay/silage	50% - 60%
-	Mature crop (hay/silage)	30% - 50%
-	Mature crop, mouldy/dusty	20% - 40%

3.3 Nutrient Density and Structure Value of a Feedstuff

Nutrient density (digestibility) and structure value of a food are both related with CF (cell-wall) content. The higher the cell-wall content, the lower the nutrient density and the higher the structure value of a food. Nutrient density of a food is defined as its energy content per kg DM. Digestibility of a food is closely related to nutrient density (and CF content). The digestibility values can be used as a guideline for the nutrient density (see Chapter 3.4 and appendix 2).

The nutrient density values are usually 5-10% below digestibility values (D% or DC). The nutrient density is important. If it is too low (<50% digestibility in the DM) its use in feeding dairy is limited. Therefore, low quality/density feedstuffs (roughage) must be balanced with feedstuffs of high density (concentrates). A cow producing 10 kg of milk requires at least 65% digestibility in the DM.

On the other hand, to assure good rumen functioning and to avoid that rumen mass may become too much compacted, the ration must contain sufficient "structure-materials" (fibre), indicated by structure value. Structure value is expressed on a scale from 0 - 1.2 (on DM base). Long, dry roughage have a high structure value (1 or more), while concentrates have little or no structure value (< 0,2). A practical recommendation is, that at least 1/3 of the total DM of a ration is "structure value". In Poland, roughage has generally a rather high structure value (1 or more). The general guideline is that at least 30% of the total DM of a ration should be roughage. To preserve the structure value of a roughage, it is necessary to have a chopping length of over 1 cm. A thorough list of feedstuffs and their structure values is given in appendix 3.

Feedstuff	**Structure value**	**% DM**
Straw	1.2	90
Good quality grass hay	1.0	85
Wilted grass silage	0.7-0.8	40
Maize silage (0.8-1.0 cm long)	0.6	25
Pasture grass	0.5-0.6	15
Concentrates	0.0	90

3.4 Digestibility

The digestibility of a food is most accurately defined as the DM proportion not excreted in the faeces, and therefore to be assumed absorbed by the animal. The digestibility of a food is commonly expressed as a coefficient or % DM.

Example
A cow consuming 9 kg of hay with a 90% DM content has a DMI of 8 kg. In the faeces 3 kg of DM is recovered (DMO). In formula:

DC = DMI – DMO/DMI = 8 - 3/8 = 0.625
D% = DMI – DMO/DMI * 100% = 62.5%

with DMI Dry Matter Intake (DM eaten)
DMO Dry Matter Output (DM in faeces)

The D-value gives an indication of the digestibility. This is only a practical guideline. One should remember that digestibility is influenced by breed, type and individuality of an animal, type of ration and level of feeding. Therefore, the DC or D% can show different values. If DC or D% are not available, TDN values can be used as an indication of digestibility. The TDN values are at least suitable for comparing the assumed digestibility of different foods (ranking order). The digestibility values will in general be slightly higher than the reported TDN values (5-10%). A separate list with D-values is given in Appendix 2.

An indication of quality is:

Digestibility % :	over 70%	= good digestibility
	60-70%	= moderate digestibility
	40-60%	= low digestibility
	under 40%	= very low digestibility

3.4.1 The Influence of Digestibility

The Digestibility of a ration has an influence on *heat-increment* and *DMI*.

3.4.1.1 Influence of Digestibility on Heat-increment

There is quite a variation of heat-increment between different feedstuffs, 40-80% from ME into NE. This difference depends for a big part on digestibility. Poor digestibility (poor quality roughage) leads to high heat-increment. An aspect especially to be considered for warmer climates/seasons, and feeding during hot parts of the day. For Poland, this will be exceptional, and only applicable during a hot summer. In this case, some of the consequences are:

- to avoid heat-increment peaks by offering roughage ad lib
- to offer at least roughage during the night
- to consider aspects of housing (roof, ventilation)
- to provide shade in daytime in the yards, especially above feeding areas and drinking troughs
- to offer good quality roughage, which is essential for a high intake of food as to reach high production levels
- to distribute concentrates evenly during feeding (minimum 3-4 times/day)

3.4.1.2 Influence of Digestibility on Dry Matter Intake (DMI)

If a food is not digested easily, it will stay longer in the rumen. The rumen will remain rather full and the cow does not develop a physical feeling of hunger. Therefore the cow will eat less (lower DMI) and consequently produce less milk!

Importance of a low digestibility food intake is indicated by following example:

Example
With a certain grass, with two different D%, it was found that:

1. D% = 60%, and DMI = 80 gr DM per kg bodyweight
2. D% = 40%, and DMI = 50 gr DM per kg bodyweight

A decrease of 33% digestibility (from 60% to 40% = 20/60 * 100% = 33%). The intake of digestible DM decreased from 48 gr/kg bodyweight (0.60 * 80) to 20 gr/kg bodyweight (0.40 * 50): a decrease of almost 60% (28/48 * 100%)!

This indicates a very important principle in cattle feeding. The higher the digestibility of a food, the higher the DMI. This results in a proportionally increase of total nutrient intake and, naturally, vice versa!

Conclusion
If a food is of a good quality, an animal will eat <u>more</u>. If quality is lower, than an animal will eat less with all consequences in performance. One should notice that a high digestibility of a food indicates a low CF contents and consequently a high nutrient contents.

3.4.2 Factors Affecting Digestibility

Various factors are affecting the level of digestibility:

1. Food composition
2. Ration composition
3. Preparation / treatment of food
4. Feed additives
5. Level of feeding
6. Animal Factors

3.4.2.1 Food Composition

The CF fraction (lignin) and ash fraction (silicium, soil) are important factors in the digestibility of a food. More mature roughage will have a lower digestibility.

3.4.2.2 Ration Composition

In a ration, the total CP (or DCP) contents and available energy are important. There are associated effects (balance in quality) amongst different feedstuffs. These associated effects can be positive or negative.

3.4.2.3 Preparation / Treatment of Food

→ Milling, grinding, and crushing
- Essential for cereal grains and pulses

→ Boiling
- No real effect for ruminants

→ Chopping
- No real effect on digestibility
- Reduces selectivity and therefore requires better quality supplement
- May reduce losses when chopped < 15-20 cm (long hay, stover, straw)
- Below 1 cm loss of structure value consider labour and machinery input

→ Fine chopping/grinding of roughage
- Nett effect not positive
- 20% less fibre digested as food passes quicker through rumen
- Loss of structure
- Change of VFA's (less acetate)

3.4.2.4 Feed Additives

As for treatment of straw for low production systems (extensive production), Urea is a possible additive. NPN as an additive is not advised in high yielding dairy production systems.

3.4.2.5 Level of Feeding

A higher level of feeding may reduce the digestibility as food passes quicker through the rumen, but less degradation of protein in the rumen is possible. The nett effect is not clear. Reduction on digestibility due to increased passage rate (rumen turn-over rates) are greatest for the slowly digested components (cell-walls/fibre). The greatest reduction of D% with increased feedings level are found with ground and pelleted roughage and some fibrous by-products (straw, stover, chaff). Digestibility may be reduced by as much as 20%.

3.4.2.6 Animal Factors

Differences occur between breeds and individuals. This last aspect offers some scope for selection (records!).

3.5 Minerals and Vitamins

See for details Chapter 1.

3.6 Special Aspects

Special aspects to be considered for feed evaluation are:

- Constant availability of quality volumes
- Constancy/reliability of supply, transport, handling & storage requirements
- Influence on milk production (cabbage and brewers grain usually have a positive effect)
- Influence on milk quality (smell, taste, colour, quality of butterfat)
- Certain toxic or other substances like aflatoxin in groundnut products, gossypol in cottonseed cake, goitrogenic substances in Brassica family, oestrogenic substances and mimosine in legumes
- Possible contamination or adulteration (soil, sand, dirt, chaff, sawdust etc.)
- Palatability, usually closely related to digestibility
- Factors affecting digestibility like tannin

3.7 Physical Judgement of the Feedstuff

If possible, feedstuffs could be physically examined to assist in the evaluation of quality. Judge the overall quality in relation to the average product, using all senses (feel, look, taste, smell) and your experience. One should have the same approach to all other kind of products (vegetables, molasses etc.).

3.7.1 Roughage

- Estimate maturity, indicating fibre contents and digestibility (coarseness)
- Look at the ratio *leaf : stem*
- Determine species and possible varieties, as well as length
- Hay colour:
  - yellow/green → good
  - yellow/grey → medium
  - brown/black → poor
- Mould, dust, smell to be checked
- Presence of weeds, thorns etc.
- Silage
  - smell (butyric acid)
  - wetness, structure
  - colour
  - soil contamination

3.7.2 Concentrates

- Rancidity (keeping quickly, palatability)
- Smell, colour, taste
- Texture
- Contamination
- Mould

3.8 Prices

Price comparisons are discussed in Chapter 5.6.3.

CHAPTER 4
CLASSIFICATION OF FEEDSTUFFS

Introduction

Various classification systems are employed to differentiate feedstuffs, each according to a certain purpose.

Classification of feedstuffs divided **by origin** into three categories:

1. Plant origin	→	Roughage and concentrates
2. Animal origin	→	All products have a high energy content and often a high protein content They are considered concentrates, except for poultry manure, as it has a high CF contents
3. Chemical	→	Used in feeding when CP in ration is (too) low

Classification of feedstuffs is divided **by CF%** into two main categories:

1.	Roughage	→	With a CF% in the DM *higher than 18%* usually vegetative plant parts
2.	Concentrates	→	With a CF% in the DM *lower than 18%* ripe seeds/grains or products derived from these

Artificially dried roughage is considered an intermediate between roughage and concentrates. Classification is divided by **digestibility percentage** into four groups:

Digestibility percentage:	over 70%	= good digestibility
	60 - 70%	= moderate digestibility
	40 - 60%	= low digestibility
	under 40%	= very poor digestibility

Within the classification, suitability of feedstuffs for feeding can be categorized according various qualities: DM, feed value, structure, maximum intake, tenability, preservation, labour at feeding and storage provision.

4.1 Classification of Feedstuffs by Origin

Feedstuffs can be divided into *plant* and *animal* origin. The latter is less important in animal nutrition. Within this classification, feedstuffs can be categorised into *roughage* and *concentrates*, respectively reviewed in paragraph 4.2 and 4.3.

4.1.1 Feedstuffs of Plant Origin

Feedstuffs classified according **origin and composition** can be divided into three groups, the majority categorised as roughage.

1. Farm products
2. By-products from agricultural industries
3. Artificial dried fodders

4.1.1.1 Roughage From the Farm

→ With high moisture content, fresh products like grass, tubers, roots, silage
→ With moderate moisture content, like wilted silage;
→ With low moisture content, like hay, straw, stover;
→ Miscellaneous, like fruits, pulp.

4.1.1.2 Roughage By-products From Agriculture Industries

→ From sugar industries, like pulp, bagasse
→ From breweries, like brewers and distillers grains
→ Fruit juice/packing industries, like fruit pulps

4.1.1.3 Artificial Dried Fodders, Like Grass and Lucern Meal-pellets

As far as known this way of producing feedstuffs is not often practised in Poland. In The Netherlands artificially drying of grass is especially done in the western parts of that country. The dried pellets are used for e.g. horse breeding.

4.1.2 Products of Animal Origin

These products can be divided into four main groups, most of them categorized as concentrate:

1. Milk and milk by-products (fresh or dried)
2. Products from meat and carcass-industry, e.g. meatmeal, bonemeal, blood meal and feather meal
3. Products from the fish industry like fish meal and shrimp meal
4. Manure of poultry & pigs can be used in the nutrition of ruminants (Their CF content is too high to be classified as concentrates!)

4.1.3 Products From the Biochemical Industry

- Urea and biuret (NPN sources)

4.2 Roughage

Roughage can be divided into seven main groups:

1. Grasses (pasture)
2. Legumes
3. Fodder crops
4. Agricultural by-products
5. Conserved fodders
6. Industrial roughage
7. Miscellaneous feedstuffs

4.2.1 Grasses (Pasture)

Generally, grasses and its products are the main supplier of roughage in most countries with an advanced dairy-farming system. Pasture (grasses) provides a basis for dairy-production. They are abundantly available and with their good quality (usually) the cheapest source of food for cattle.

Unfortunately, the quality of grasses in development countries can be rather of poor quality. The availability may be limited due to land pressure (first priority is to provide staple food for human nutrition) and/or high production costs.

The poor quality is mainly due to:

- Type of grass (varieties, species). Tropical grasses and natural grasses in temperate climates have often a lower protein content and lower NFE (N-free extract, e.g. starch, sugars), while the CF contents is (much) higher than in well managed special selected temperate grasses.

- Maturity is usually reached earlier and flowering may be continuous, also due to climatic and soil factors.

- Quality of grass is affected by management factors, such as:
  - Fertilizer input. Low or non N input results in lower CP contents and lower quantities of product.
  - Stage ad method of harvesting. Late harvesting (over-mature) provides more bulk but the product will be of poor quality (CF).

- Method of conservation. Usually, warm and humid climates provide a rather poor environment for conservation (hay making, silage making), while similar factors contribute to losses during storage (mould due to moisture).

All in all, the nett result often is a rather poor quality and yield. Grasses and its conserved products do have often a much lower digestibility and feeding value.

A low digestibility and feeding value, together with limited availability of grass (in general *roughage*) complicates making a balances ration for high yielding dairy cattle. In other words: to judge the proper amounts and quality of the supplement concentrates required is more difficult! Low digestibility and feeding value affects the DM intake in a negative way, which results in a more than proportional lower intake of nutrients! The limited amount of nutrients obtained from poor quality roughage should be balanced by towering amounts of usually expensive high quality concentrates. This leads to an increased cost-price of milk, as feeding is the main factor in the total cost-price. Sometimes, feeding costs are up to 60% of the total cost-price per kg milk.

A low digestibility and feeding value often leads to sub-optimal feeding levels and strategies of the potentially high yielding dairy cattle, causing a poor production, low fertility, high incidence of diseases, and disappointed farmers and managers. Availability of good quality concentrates is often limited (or expensive) and strong competition may exist with the monogastric animal production systems (pigs & poultry) and/or export (foreign currency, policy priorities). The expensive (imported) dairy cattle, however, never get a real chance to express their genetic potential for high milk production, but under the above described conditions, the **blame should not be put on the cow**!

However, developing countries do not always produce sufficient milk to meet the relatively low, but probably rising demand for milk. Only policy decision can solve the following dilemma:

- To moderate production levels from available food resources at reasonable prices. Milk production is a *by-product* from the agricultural system and is related to the reality of food prices, food quality and milk prices.

- To allow a high cost-price to realize high milk production levels to express the cows' full genetic potential.

Grasses can be used by grazing or zero-grazing (mowing, cutting and feeding in the corrals, yards, barn or shed: the so-called "cut and carry" system) or can be fed after conservation (hay, silage). Every type of utilization results in losses:

- **Grazing**
  Losses of 25-30% as a result of trampling, urine/dung patches and refusal.

- **Zero-grazing**
  Selective intake may require 10-35% extra feeding to allow for refusal. If the product is chopped (<5 cm), no selective intake can take place. In this case, the average quality is lower resulting in lower DMI and the need for more and better quality concentrates (balancing the ration).

- **Conservation**
  Losses up to 30% DM in the silage. Losses of nutrients can be even higher (DCP up to 60-70%) due to refusal, soil contamination, side losses in the pit and risk of quality. In hay making there are losses due to weather conditions, leaf losses, storage and refusal.

Conclusion

It can be said that animal production on grass depends on:

- Herbage availability
    - · land
    - · yield
- Herbage quality
- Herbage intake (related to a = b)
- Losses during conservation and/or feeding

4.2.2 Legumes

The feeding value of legumes (lucerne, alfa alfa, clovers) varies less when compared to grasses. Protein and mineral contents are often higher, whereas the CF content is lower compared with grasses. Legumes have a high calcium, but a low phosphorus content. Some legumes (clover, lucerne) are able to produce large amounts of high quality fodder under intensive management conditions. Legumes differ a.o. from grasses as their growing points are higher above the ground. Legumes do not allow close cutting (or grazing). In order to obtain high yields irrigation may be necessary. Especially to sustain yields during the dry season. Legumes can be conserved as hay, but leaf losses may be very high. They are less suitable for silage making. The inclusion of some fresh legumes in a diet can be very beneficial for a high yielding dairy cow.

4.2.3 Fodder Crops

The most common fodder crops are: roots, beets, carrots, cassava, turnips, swedes, mangolds, tubers (sweet potatoes + vines, potatoes), fodder grains (maize, sorghum, oats, rye) and Brassica species (kale, cabbages, rape). The main advantage of these fodder crops is, that they are capable of producing high yields per/ha, often during periods when other roughage (grass) are in short supply. Frequently they are produced on irrigated land and can be fed fresh or conserved (maize silage), while some products can be relatively easy stored (tubers, roots).

Roots, tubers and Brassica species have a low DM% (10-20%) and are relatively rich in energy, supplying nutrients like starches and sugars. Their CF content is low which results in a high digestibility (and palatability). Their protein content is generally low, as well as their mineral/vitamin contents with the exception of carrots, which are rich in vitamin A.

Fresh/green fodder crops provide a welcome component in a diet, especially where dried roughage and concentrates are prevailing. Care should be taken with the laxative effect these fodder crops generally have, which may cause diarrhoea (introduce gradually) and may depress the fibre digestibility of other components of the ration.

Fodder grains can give high yields: relatively energy rich roughage per unit land. The feeding value depends largely on the quantity and maturity of the seeds included. Sometimes, seeds are harvested for human consumption. This reduces the feeding value of the remaining plant. The protein content is relatively low. Maize is an excellent product for silage making, sorghum can provide several cuts of fresh material (irrigation and cutting at immature stage).

Sorghum should not be grazed during the first 3-4 weeks after cutting. Sorghum may contain a rather high amount of prussic-acid in the young stage, causing poisoning (death).

4.2.4 Agricultural By-products

Only a part of agricultural products can be utilized by man himself. The amount of by-products for feeding farm animals can be considerable. There is a considerable variation in quantities and qualities of by-products between crops, influenced by species, varieties, climate, season, region and stage at harvest. The most important parts of roughage are the aerial parts (stems, leaves). These can be utilized fresh or dry, cut or grazed, in the field or in the stable/barn.

The most common agricultural by-products are:

- **Straw of legumes**, like lupin, with a rather high nutritive value (if properly handled and stored after harvesting).

- **Cereal grains give straw, stubble, stovers, and chaff as by-products**. On average, most cereals yield equal amounts of grain and straw per ha. The quality of straw is very variable, but in general quite low. Generally P content is low and the Ca not easily absorbed, while the very high Silicium (Si) content depresses digestibility.

- **Sugar beet tops and residues** can be an important by-product from agricultural production. The energy content could balance the hay silage feeding (with high content of protein). Often, these residues can be obtained from sugar factories. Include costs for transport when considering sugar beet residues (it has a high percentage of water [85 %], therefore costs per kg dry matter should be calculated beforehand).

Summarizing, most agricultural by-products (roughage) have a rather low feeding value, which implies that they need supplementation with concentrates to enable high milk production.

4.2.5 Conserved Roughage

Roughage can be conserved into hay or silage. Losses during the conservation process and storage can be 30-50% of the DM, due to continued respiration, leaching by rain, mechanical handling and self-heating. The losses depend on the climate and the success and speed of the conservation process. Generally, losses of energy and DCP are even higher, up to 75%, leaving a conserved product with a low quality compared to the original product. Before

fodder conservation is practised, the real feasibility of conservation should be determined, as well as the extra costs for equipment. Modern conservation methods (wilting, quick harvesting and proper sealing) can reduce losses in silage making considerably (15-20% DM).
The course book on Grassland Management and Fodder Production elaborates on this subject.

4.2.6 Industrial Roughage

By-products from several agricultural industries can be used as roughage for ruminants. Their disadvantages are an often high water content, which affects keeping quality and makes transport more difficult, while the feeding value varies frequently. For those reasons, their use is generally limited to farms in the vicinity of the industrial plants.

4.2.7 Miscellaneous Feedstuffs

Chicken manure or litter is quite a valuable "roughage". It contains excrements of poultry, which consists of undigested parts of the feed and the metabolic products with a high NPN content, wasted poultry feed and bedding material. Its feeding value varies, but on the average it has an energy content of 760 FUM and 20-25% DCP in the DM.

4.3 Concentrates

Concentrates are mainly derived from the following sources:

1. Cereal grains
2. Pulsus
3. Other seeds & parts
4. By-products from agricultural industries:
   → Oil industries, like *cakes*
   → Milling industries, like *bran*
   → Sugar/alcohol/fruit industries, like *citrus pulp*, *beet pulp*, *brewers grain*
5. Animal products
6. Industrial feedstuffs

4.3.1 Cereal Grains

They have a DM content of 85-90% and only contain small quantities of CF. Fat content is usually low (1,5-5%) and protein is of moderate quality. Mineral content is not high. DCP varies from 5% (sorghum) to 10% (wheat). Their main function is to provide energy. Usually, there is a strong competition for cereal grains for human needs and the feeding of monogastric animals (pigs & poultry) and the price may be high.

4.3.2 Pulses

The main difference with cereal grains is their higher protein content, from 15-30% DCP. In some cases they also contain large amounts of fats. CF content will be decreased considerably if the pulses are dehulled.

4.3.3 Other Seeds & Parts

Other seeds, e.g. sunflower seeds and cotton seeds are used as feedstuffs. When dehulled and/or decorticated they have a high energy (fat) content.

4.3.4 By-products From Agricultural Industries

From several agricultural industries, by-products become available as feedstuffs for animals. The main by-products are divided into 6 groups:

1. Residues from oil and fat industries (cakes, meal);
2. By-products from milling industries, e.g. bran, pollard, polishing, etc. Corncob meal is specially made for animals. It has a low feeding value;
3. By-products from starch industries, e.g. gluten & cassava/potato residues;
4. By-products from sugar industries, e.g. beet pulp (dried) and molasses. Molasses can be used in rations, e.g. included in concentrates. It facilitates pelleting. In many countries it is a relatively cheap source of energy and can be used to improve taste. Molasses are also used as an fermentation agent in silage making of grasses;
5. By-products of the fruit industries like citrus pulp, pineapple pulp etc.;
6. Miscellaneous products, like bean curd residue.

4.3.5 Animal Products

Animal products are mainly:

1. Milk and its by-products
2. Slaughter house by-products
3. Fish products

4.3.6 Industrial Feedstuffs

Sources of NPN like urea and biuret.

CHAPTER 5
CONCENTRATED FEEDS FOR DAIRY CATTLE

Introduction

Concentrates (also mixed feeds, compound feeds or concentrate mixtures) play an important role in modern dairy cattle feeding. Usually, as a basis of most dairy production systems, concentrates are used as a supplement to roughage. Although a specific ingredient can be called *concentrate*, practically it is a mixture of several ingredients mixed in a way as to cover requirements (energy, proteins, minerals and vitamins) of an animal at the least possible costs. The quantity and proportion of ingredients can vary (economics!), but the feeding value of a final concentrate should be kept constant according the requirements.

5.1 The Necessity for Concentrates

In high yielding dairy cattle, it is very difficult (or impossible) to meet nutrient requirements for maintenance and (high) production from only roughage. Poland experiences a constraint in production and utilization of roughage (in aspects of quantity, quality and economics). The digestibility of roughage is often low. This depresses the DMI. The quantity may be limited, and causes an increased demand and/or quality of concentrates. High yielding dairy cows need a better quality diet (tighter protein: energy ratio) than low yielding animals.

In comparing energy and protein requirements for a 600 kg cow at different production levels, respectively 1, 5, 10, 20 and 40 kg (all at 4% butterfat), results are presented in table 5.1.

Table 5.1: Energy & Protein for a 600 Kg Cow at Various Milk Yields (4%)

Requirements for:	**FUM**	**DCP (gram)**	**FUM / DCP**
1 kg milk only	460	63	1 : 7.3
maintenance only	5013	390	1 : 12.8
maintenance + 1 kg milk	5450	450	1 : 12.1
maintenance + 5 kg milk	7250	710	1 : 10.2
maintenance + 10 kg milk	9500	1020	1 : 9.3
maintenance + 20 kg milk	14100	1650	1 : 8.5
maintenance + 40 kg milk	23800	2910	1 : 8.2

Not only the required amount of food increases with increasing production, but also the quality of the requirements increases (DCP : FUM ratio getting tighter).

Conclusion

More and better quality concentrates are necessary when:

→	Roughage is of lower quality and/or is offered to a limited amount
→	The animal produces more

Concentrates, as their name implies, are feedstuffs with a high energy and/or protein content per kg and a high digestibility (> 70%), and are consequently very suitable to increase the overall nutrient concentration of the ration. If the use of high amount of high quality concentrates is financially attractive depends on the economic context, in which the dairy production takes place (milk prices, subsidies, government politics etc.). The supply of concentrates besides roughage tends to increase the voluntary intake (DMI) under ad lib roughage feeding systems (increases overall digestibility), although some substitution of roughage for concentrates will take place in feeding systems, that offer a high amount of roughage (see Chapter 6).

5.2 Types of Concentrates

Of course the type of concentrates required depends very much on the quality and quantity of roughage offered to the different classes of animals. In general the following types of concentrates can be distinguished:

1. **Early weaner mixture**: for young calves up to 5-6 months (minimum till one month after weaning), with a minimum DCP content of 18-20%

2. **Young stock mixture**: for young stock from 6 months till ± 1½ years of age, with a minimum DCP content of 15-17%

3. **Medium protein mixture**: for young stock till calving, dry animals and possibly animals in late lactation, with a DCP content of 12-14%

4. **High yielding mixture**: for cows in early lactation (up to 12-15 weeks), with a minimum DCP content of 15-17%, to allow for high milk production from mobilized body reserves (*milking from the back*)

5. **Standard mixture**: for high yielding cows in the second lactation stage, or medium yielding cows, with DCP content of 12-14%

As concentrates are usually used as a supplement in balancing a roughage diet, the actual quality (expressed in DCP %) depends on the actual amount and quality of roughage offered. Although single ingredients can be used, mixtures of ingredients are more common. In supplementary concentrates it is necessary:

1. To reach the proper ratio of protein : energy per category of livestock;
2. To supply deficiency quantity of protein and energy (production level);
3. To include possible deficiency of minerals and vitamins;
4. To reach the most economical mixture (least costs calculation);
5. To counter balance certain characteristics of individual ingredients, such as taste, fat content, certain substances like gossypol, laxative aspects such as molasses (see also Table 5.2).

In many cases protein is the main lacking ingredient, especially in high potential yielding cows. More over, protein is usually the most expensive ingredient. Therefore, economics may not allow to express the genetic potential of a high yielding cow.

5.3 The Essentials of a Good Concentrate

Energy
Concentrate (mixtures) should have an energy content of over FUM 1000 per kg DM as to have a minimum possible production response of at least 2 kg of milk per kg of concentrates. If a concentrate contains less than FUM 1000 per kg, it indicates a high CF or ash content. A high CF/ash content is not desirable when roughage is of medium/low quality. This generally is the case. CF reduces the feed density and digestibility following by an increasing heat-production and consequently depresses appetite. Especially brans, hulls and chaff of cereal grains have a high CF content. A high CF content indicates *adulteration* (chaff, husks, sand, sawdust) as a result of poor or/and unhygienic handling. In order to increase energy value and/or to improve the taste, molasses could be added as to avoid diarrhoea (up to maximum 15% for adults and 5% for calves).

Fat
Good concentrate contains at least 3% crude fat, accomplished by the inclusion of by-products from oil-seeds. However, under warm and humid conditions the fat may quickly become rancid affecting the keeping quality. Rancidity affects the intake as the product becomes less palatable.

Crude Fibre (CF)
Concentrates for calves (early weaner mixture) should not contain more than 9 % CF, as the rumen of the young calve is not yet completely functioning. Cotton seed cake can not be included in the concentrate for young calves, as the gossypol in the cake acts as a poisonous substance for calves.

Minerals
Inclusion of at least 3% mineral mix is desirable. The mineral mix should contain the major- and trace-elements. The recommended quantities depend on local conditions, such as soil type, type of forage, type of concentrates, production level. Furthermore, it is recommended to provide NaCl (common salt) ad lib, either as a "*lick*" or dissolved in water (2½ % = 2½ kg salt in 100 litre water).

Vitamins
In indoor cattle keeping systems, vitamin D may have to be supplemented in the concentrates (calves, young stock). If rations are devoid of fresh, green, leafy materials extra vitamin A may have to be supplied (calves, young stock). In general, inclusion of 0.1% vitamin AD3 preparation is recommended.

Consistency
To reduce losses and to stimulate quick intake, concentrates could be offered as a thick porridge. The porridge should not be prepared more than 4 hours before milking/feeding. Dry meal (without the availability of drinking water) increases losses and reduces the speed of intake and possibly the overall appetite. It is therefore not recommended.

5.4 Quality and Maximum Allowance of Ingredients

Proper information should be available and obtained about the quality of ingredients as to allow to compose a balanced mixture at least-costs.

Table 5.2: Some Maximum Allowances of Ingredients in Concentrates for Rations in Which Concentrate Has a Maximum of up to 50% DM

Product	Maximum % in mixture	
Maize by-products	40-50%	
Wheat by-products	25%	
Rice ban	0-20%	
Malt germs	10%	
Coconut products	50%	
Groundnut cake	20%	
Cottonseed cake	20%	(not for calves)
Sunflower cake	10%	
Rapeseed cake	10%	(goitrogenic substances)
Molasses	15%	(5% for calves)
Sugars	5%	
Slaughter by-products	limited	
Fish meal	5%	

In general, ingredients should be checked for mould, soil contamination and residues (e.g. sweet potatoes and cassava). But also particular aspects have to be considered. Examples are:

Gossypol contents →	in cottonseed products
Aflatoxin →	in peanut products
Goitrogenic substances →	in rapeseed
Hairy seeds →	like cottonseed, should be decorticated (hairs/fibres removed)
Sugars / molasses →	can only be used in limited quantities: it may cause diarrhoea;
Sugars →	may depress utilization of the ration it results in excessive amounts of methane gas. It either escapes unutilized and/or causes a decrease of the pH in the rumen, to fall below level 6;
Mouldy and/or sour products →	are to be taken care off;
Maize and rice products →	used in mixed feeds should be limited in quantity. It might result in production of (very) soft butterfat, which turns rancid quickly;
Soya beans →	in large quantities are undesirable due to their high fat content;
Sesame and sunflower products →	are less tasty. Ratio of some ingredients depend on the percentage of hulls and husks.

5.5 Mixing of Concentrates

Mixing of concentrates can be done on the farm or in special plants. Mixing on the farm can be done simply by using a spade. It is best to start with the ingredient taking part in highest proportion. The remaining ingredients are added in order of decreasing proportion, minerals and vitamins last. Then the mixing can start, using the spade to make the mixture as homogeneous as possible. The incorporation of urea in these "home-made" mixtures is not recommended because of the risk of poisoning.

5.6 Calculating Compositions

Nowadays, most mixed feeds are composed with the aid of computers, which are able to combine several ingredients in such a way, that the cheapest mixture with the desired feeding value is obtained with similar DM values.

5.6.1 Composing A Ration From Two Ingredients

In composing simple rations from two ingredients, it is possible to use the "*Pearson Square Method*". An example of this method is presented, using DCP content. It is also possible to do this with energy (FUM). The procedure for calculation is as follows:

- Make a square and place the desired DCP % of the mixture in the centre of the square.

- Place the DCP % of the 2 available ingredients at the upper (A) and lower (B) left-hand corners of the square.

- The difference between the figure in the left-hand corner and the desired DCP % is placed in the diagonal right-hand corner of the square. The figure at the upper right-hand corner is the number of parts of feed A that must be used and the figure at the lower right-hand corner the number of parts that must be used of feed B.

Example

A mixed feed with 16% DCP in the DM is required. Available ingredients are:

-	Maize meal	7% DCP, 1210 FUM
-	Soya bean cake	40% DCP, 1150 FUM

To solve this problem and obtain the mixture with 16% DCP, the Pearson Square Method is used in the following way:

-	Maize meal	7	→	24 parts A	(40-16)
				16	
-	Soya bean cake	40	→	9 parts B	(7-16)
				33 total parts (in weight)	

The mixture consists out of 24 parts maize meal and 9 parts soya bean cake.
Or, when expressed in percentages: maize meal 72.73 % (24/33 * 100 %) and soya bean cake 27.27 % 9/33 * 100 %). The ratio of soya bean cake and maize meal is:
72.73/27.27 = 1 kg : 2.67 kg.

To check the level of the DCP%:

- maize meal	24/33 * 7 % DCP =	5.09% DCP
- soya bean cake	9/33 * 40 % DCP =	10.91% DCP
	Total DCP %	**16.00% DCP**

The FUM content of this mixture is:

	- maize meal	24/33 * 1210 FUM =	880 FUM
- soya bean cake	9/33 * 1150 FUM =	314 FUM	
	Total FUM %	**1194 FUM**	

5.6.2 Composing a Ration From Three Ingredients

For reasons of economics and overall feeding value it may be attractive to mix three available ingredients (with similar or converted DM contents) into a concentrate with a certain minimum required nutritive value.

Example: a concentrate is required with a medium protein content of 130 gram DCP/kg and the following ingredients are available:

Ingredients	FUM (per kg DM)	gram DCP (per kg DM)
- wheat bran	818	125
- maize meal	1210	65
- soya bean cake	1150	460

How to make the required mixture (13% DCP)?

First, the difference is calculated between the desired DCP and the content of each ingredient:

- wheat bran	125 - 130	= - 5
- maize mea	170 - 130	= - 65
- soya bean cake	460 - 130	= + 330

Two of the ingredients contain less than the desired DCP contents and one ingredient contains more. These differences are to be combined in such a way that they add up to about zero. Then the mixture has its desired DCP content.

	Difference	Multiplication	Balance
- wheat bran	- 5	1	- 5
- maize meal	- 65	5	- 325
- soya bean cake	+ 330	1	+ 330
		7	0

The multiplication factors indicate which proportion each ingredient contributes to the desired concentrate (13% DCP in DM). The desired concentrate consists out of 1/7 wheat bran, 5/7 maize meal and 1/7 soya bean cake. It is possible to check if the answer is correct. If 7 kg DM of the desired concentrate is made, then the total protein content is: 7 * 130 = 910 gram DCP.

	FUM		gram DCP	
- wheat bran contributes	1 * 818 =	818	1 * 125	= 125
- maize meal contributes	5 * 1210 =	6050	5 * 65	= 325
- soya cake contributes	1 * 1150 =	1150	1 * 460	= 460
		8018		**= 910**

Per kg mixture DM there is: 8018/7 = 1145 FUM and 910/7 = 130 gram DCP.

In 100 kg DM of mixture there is:

- wheat bran	1/7 * 100 kg = 14.30 kg DM
- maize meal	5/7 * 100 kg = 71.40 kg DM
- soya bean cake	1/7 * 100 kg = 14.30 kg DM

Ratio (on DM basis) wheat bran : maize meal : soya bean cake is 1:5:1

Note: *It is necessary that all calculations are based on DM values. When formulating a concentrate, given quantities are to be converted from DM into fresh material as to take water contents of the ingredients into account. In many cases however, ingredients of concentrate feeds have a DM content of ± 90%. Therefore, calculated proportions of ingredients on a DM basis might not differ much from the "fresh material" basis. Wet products, such as brewers grain waste and soya bean curd residue, are fed separately and thus not included in the mixtures.*

5.6.3 Price Calculations and Comparisons of Values

In order to prepare the most economical mixed feed, it is essential to use the cheapest available ingredients with the highest feeding values. Several aspects and limitations are to be taken into account, such as: maximum allowances of certain ingredients, toxic substances, and fat content. Prices of individual feeds should be compared on basis of their feeding characteristics, in which **energy** and **protein** are most important. When a feed has a special attractive or negative character subjective adjustment can be recommended, such as for taste and good or bad influence on milk production.

Following example shows a widely used method to realize price comparisons between individual feedstuffs. The method is based on the average feeding values and the estimated prices of feedstuffs per June 1990.

Example
The feedstuffs mentioned in table 5.3 and 5.4 are available on the market. They are grouped into "protein rich" and "energy rich" feedstuffs and their contents (energy and protein on DM basis) and prices are presented in Plz per 100 kg.

Table 5.3: Prices and Values of Protein Rich Feedstuffs

Feedstuffs	FUM (units)	DCP (kg)	Price Plz/100
Soya bean cake	1005	413	80
Bean curd residues	950	180	60
Fish meal	1050	500	63
Cottonseed cake	805	250	75
Groundnut cake	870	460	70
Total	**4,680**	**1,803**	**348**

(source feeding values: Feeding Standard for Dairy Cattle - 1987)

Table 5.4: Prices and Values of Protein Poor Feedstuffs

Feedstuffs	FUM (units)	DCP (kg)	Price Plz/100
Maize meal	1050	60	83
Brewers grain	980	78	60
Starch residue (cassava)	1060	35	65
Wheat bran	850	115	58
Maize cob	860	54	65
Total	**4,800**	**342**	**331**

It should be realized that many aspects, such as of transport, handling, storage, keeping quality, and milling, are not considered in the above mentioned prices.

The five protein rich feedstuffs together contain 4680 units FUM and 1803 kg DCP with a total price of 348 Plz. With the price of energy per unit FUM (Pe) and the price per kg DCP (Pp), the following equation is valid:

a) $4680 * Pe + 1803 * Pp = 348 \quad \rightarrow \quad (A)$

The same can be done for the 5 protein poor feedstuffs:

b) $4800 * Pe + 342 * Pp = 331 \quad \rightarrow \quad (B)$

Based on the two equations with 2 unknowns, Pe and Pp can be calculated:

FUM A / FUM B		4680/4800 = 0.975* equation B = equation C	
$\rightarrow$	C	4680 * Pe + 333.45 * Pp =	322.7
	A	4680 * Pe + 1803 * Pp =	348
	-B	4680 * Pe + 333.45 * Pp =	322.7
		1469.55 * Pp =	25.3
$\rightarrow$		Pp = 25.3/1469 = 0.0172 Plz per kg DCP. Substitution of Pp = 0.0172 in equation A gives:	
$\rightarrow$	A	4680 * Pe + 1803 * 0.0172 = 348	
		4680 * Pe + 31.05 =	348
		4680 * Pe = (348 - 31.05) =	316.95
		Pe = 316.95/4680 = 0.0677 Plz per kg unit FUM	

Thus the price per unit FUM = 0.0677 Plz and the price per kg DCP = 0.0172 Plz.

With these figures, the comparative values of the feedstuffs can be calculated, multiplying its energy content with 0.0677 and its protein content with 0.0172.
There after, the ratio between the comparative value and the actual price is calculated. The higher this ratio, the more attractive the product is in **economical** point of view.

Table 5.5: Price Comparisons

Product	Real Price (RP)	Comparative Value (CV)	Ratio	Ranking CV/RP
Soya bean cake	80	75	1.07	7
Bean curd residue	60	67	0.89	3
Fish meal	63	80	0.78	1
Cottonseed cake	75	69	1.09	8
Ground nut cake	70	67	1.04	6
Maize meal	83	72	1.15	10
Brewers grain	60	68	0.88	2
Starch residue	65	72	0.90	4
Wheat bran	58	60	0.97	5
Maize cob	65	59	1.10	9

In comparing **only** energy and protein levels at market prices, the cheapest feedstuffs are: (1) fish meal, (2) brewers grain, and (3) bean curd residue. If e.g. aspects of transport, handling, storage, milling, and mixing are included in the costs per kg DCP and unit FUM, the picture might be quite different! It is remarkable than in our example the "*wet concentrates*" (bean curd residue and brewers grain) appear to be the cheapest. However, transport costs will be relatively high and control over quality will be difficult due to high moisture contents. These products require special storage facilities and do not allow for mixing with other concentrates.

The calculation allows to determine comparative values with other concentrates available in the market. For example, if sorghum (grain) is available at 65 Plz per 100 kg (RP), with FUM 1019 units/100 kg and DCP 53 kg/100 kg (DM basis), its comparative value (CV) is:

$$1019 * Pe + 53 * Pp = 1019 * 0.0677 + 53 * 0.0172 = 69.6 \text{ (CV)}$$

The ratio between its comparative value and the real price is:

$$(RP) = RP/CV = 65/69.6 = 0.93$$

Sorghum appears relatively expensive at its price (ranking nr 5). Of course, it is possible to only compare energy and protein values of a feedstuff within the class of energy rich feedstuffs. New calculations will have to be made if price fluctuations occur on the market. Similar calculations can be made to compare feedstuffs within the same class, such as wet roughage and dry roughage.

CHAPTER 6
NUTRIENT REQUIREMENTS IN DAIRY CATTLE

Introduction

This chapter reviews **nutrient requirements**, followed by ration formulation in Chapter 7.

It is difficult to compare different animals, and animals of different ages, with each other with regard to feeding and grazing. To make comparison possible, different types of livestock are converted to the same unit.

The feed intake capacity (DMI) depends on **live weight, production level** and **quality of feed**. The quantity is expressed in terms of dry matter (DM).

Standard figures are indicated for protein (DCP) and energy (FUM) requirements, divided for maintenance and production. These figures are known as **feeding standards**. In addition, standard values are given for various feedstuffs.

The variation in quality amongst feedstuffs can be immense. Specially, nutritive values can differ very much from the indicated averages! On top of that, there can be big variation in efficiency of food utilization between individual animals. There is no such thing as a standard cow. Therefore, feeding standards do have limited values. Feeding standards should be used as a guideline to individual requirement. The exact figures in the booklet should not be used as such! The figures are applicable as an average for big numbers of cattle with an expected average result. The actual performance of animals (condition and production) should be the base in feeding management. An experienced manager uses the standard values, but final decision will be influenced by actual performance. This allows the animal to proof its production capacity (within economic boundaries) and provide the manager with a proper tool for animal selection. Selection which is based on production performance of an individual animal.

6.1 Livestock Units

To make comparison possible, animals are converted to the same unit. This is called *Livestock Unit* (LU). One LU denotes the feed requirement of a standard animal of a certain live weight (usually 550 kg). With LU it is possible to compare feed needs for sheep, goats, calves and other animals with those of dairy cows. LU helps to calculate and plan the quantity of feed for a herd during a certain period. It also helps to determine how many animals can be placed on a certain field.

Table 6.1: Conversion Table

Type of livestock	LU	Norm (average Dutch herd)
Cow → in lactation	1	88%
Cow → dry	1	12%
Heifer > 18 month	0.8	40%
Yearling 12-18 month	0.6	14%
Calf 3-12 month	0.4	20%
Calf 1-3 month	0.3	20%
Calf 0-1 month	0.3	10%
Bullock	0.8	
Donkey	0.7	
Sheep, goat	0.1	
Horse, buffalo, mule	1.0	
Camel	1.1	

6.2 Nutrient Categories

Nutrients can be categorized in 5 areas:

1. Water (not an actual nutrient)
2. Dry matter (containing the nutrients, expressed as DM)
3. Energy (Nett Energy, expressed as FUM)
4. Protein (we will use digestible crude protein, expressed as DCP)
5. Minerals and vitamins

6.2.1 Water

Although water is not considered as a real nutrient, it plays a vital role in the functioning of the body, milk production, and the total intake of food (DMI). The daily requirement of water is influenced by a number of factors, such as:

→ type of food offered (DM content)
→ physiological state of animal (lactating, pregnant)
→ mineral content of ration
→ environment: temperature, humidity, and ventilation/shade
→ temperature of drinking water
→ DMI

A shortage, or uneven supply of drinking water, has a direct consequence on the DMI. In order to maximize DMI, ad lib supply of fresh water (cool in warm seasons/climates) should be available to the animal for **24 hours per day**. For maintenance, a dairy cow requires between 30-100 litres per day. For milk production, a cow requires 1-2 litres of water extra for every one litre milk production. The water requirement is estimated as 3½-4 kg per kg DMI (in temperate climates till 21 °C) plus 1-2 litres water for every kg milk produced.

More water may be required in warmer climates/seasons, also depending on the cattle keeping system (grazing, 0-grazing, housing, shade, humidity, ventilation). Peak demand (40% of total) usually occurs between 15.00 and 21.00 hours. This aspect has to be considered for the size of the trough (holding capacity, drinking space), pipe-size etc. as to supply sufficient water during the peak-demand period.

Table 6.2: Water Allowances for Cattle

Kg water per kg DMI **Class of animal**	**Environmental temperature (°C)**		
	< 16	**16-20**	**> 20**
Calves up to 6 weeks	7	8	9
Cattle (growing/adult, pregnant/non-pregnant)	5.4	6.1	7
Daily water intake (kg/head) **Lactating cows; 600 kg; milk yield (kg/day)**			
10	81	92	105
20	92	104	119
30	103	116	133
40	113	128	147

6.2.2 Dry Matter Intake (DMI)

DMI is most important in animal production, as the DM contains the nutrients. A high production will lead to an increased appetite and vice versa. The DM of a feedstuff has a slight influence on total DMI. Moderate dry (30-50% DM) and tasty feedstuffs allow highest roughage intake. Dairy ration formulation requires an estimation of DMI. The following 3 formulas are used to predict DMI of lactating cows fed on mixed diets with roughages and concentrates.

Formula 1 is considered for cows in mid and late lactation. The first 6-10 weeks lactation, DMI values are to be reduced by 2-3 kg DMI/day (energy-gap).

Formula 1: $DMI = 0.025\ W + 0.1\ Y * 1\ kg\ DM$

DMI = dry matter intake (kg/day)
W = live weight (kg)
Y = milk yield (kg/day)

Example
A cow of 500 kg and 20 kg milk production. The predicted DMI will be:

DMI =	0.025 * 500 + 0.1 * 20 * kg DM →	12.5 + 2 * 1 kg DM	
		→	14.5 kg DM/day

Formula 2 is based on a mixed diet of roughage and concentrates:

Formula 2:	Adult cows:	DMI = 8 + M/5 + Y/1,000 * 1 kg
	Heifers:	DMI = 6 + M/5 + Y/1,000 * 1 kg
DMI	= dry matter intake (kg/day)	
M	= milk production per day (kg)	
Y	= milk production per year (kg)	

Both formulas are acceptable to large dairy cattle breeds only. Another approach is to base expected DMI under conditions of ad lib roughage feeding supplemented with concentrates. Formula 3 does not only predict DMI, but also divides DMI according to the type of feed (roughage and concentrates).

Formula 3:	DMI from roughage =	1.8 - 2½ % of live weight
	DMI from concentrates =	1% of live weight

Maximim DMI
The maximum DMI is assumed to be 3½ % of the live weight, although it is recognized that DMI may as high as 4% (during and just after the lactation peak) for a short period. Fluctuations of roughage intake (1.8-2½ %) are mainly caused by the production potential of the animal and the quality (digestibility and palatability) of the roughage and apparently not completely balanced by a higher or lower intake of concentrates. This means, that the nett-result of a lower intake of poor quality roughages is mainly reflected in a lower milk production and/or reduced growth rates and loss of condition.

DMI out of roughages
The DMI out of roughages may be reduced if more concentrates are offered. This is the so-called "*forced-substitution*" effect: the DMI from roughages is partly substituted by DMI from concentrates, although the nett-result is an increase in total DMI. On average 1 kg concentrates (= 0.9 kg DM)

Table 6.3: "Forced-substitution" Effect

Feeding system	Concentrate kg	Decrease in kg DMI out of roughage p/kg concentrates
Grazing	0-6	0,3
	7-12	0,5
	13 and over	0,7
Zero-grazing	0-4	0,3
	4-8	0,5
	9 and over	0,7

More explanations and an example of calculation of "forced-substitution" is given in exercise/example 2 under point 5.1. The decision about how much DM from roughages the management should allow to be "substituted" by DM out of concentrates will mainly depend on economics and possibly quality and availability of roughages. In Poland the availability of roughages can be limited and/or sometimes expensive. The free choice of management exists only there where plenty good quality roughages are available at a competitive price in relation to concentrates and offered ad lib to the animals. Limited amounts of roughages of medium quality will however limit the production level of the cow. The ratio *roughage: concentrate* may become too narrow for a proper functioning of the rumen and/or the overall ration quality may not be sufficient for (very) high production levels.

6.2.3 Energy

Energy requirements for dairy production are expressed in Feed Units Milk production (FUM). The FUM of a feedstuff is a figure which indicates how many kg barley equals the amount of nett energy for milk production in 1 kg of feedstuff. As a rough rule, a 600 kg cow producing 15 litre per day requires **for maintenance 5013 FUM** and **460 FUM** for producing 1 kg milk. For each 50 kg weight plus or minus 600 kg a correction has to be made: - for FUM +/- 300 / 50 kg weight

For calculating the requirements for FUM we can use the following equation:
FUM= (maintenance + milk production) = $(5013 + 440\ M + 0.7293\ M^2)$

For practical use we can approach the FUM calculation by the next equation
FUM = 5000 + 460 M

In the equations above is M the milk production in kg per day expressed in kg Full Cream Milk (FCM). FCM milk has a fat content of 4% per kg.

To calculate the FCM amount for milk with a devition in fat content we can use the following equation:
FCM 4% fat = (0.4 + 0.15F) * m

F = fat content (%)
m = real milk production

6.2.4 Protein

Crude Digestible Protein (DCP) needs are expressed in **gram**. As a very rough rule, a 600 kg cow requires for **maintenance 390 gram protein** and **63 gram protein for producing 1 kg milk**.
For each 50 kg life weight plus or minus 600 kg a correction has to be made:
- for DCP +/- 25 / 50 kg weight

For calculating the requirements for DCP we can use the following equation:
DCP= (maintenance + milk production) = ((3.33 G + 1000) * 0.13) + 63 M

G = life weight
M = kg FCM

For practical use we can approach the DCP calculation by the next equation
DCP = 390 + 63 M

6.2.5 Minerals and Vitamins

Due to the local situation and prevailing soil conditions, quantities may vary. An indication for mineral and vitamin requirements of cattle is given following table.

Table 6.4: Gross Requirements for Adult Cattle of Some Major Minerals, Trace Minerals and Vitamins

Mineral or vitamin	Requirements p/day	Requirements p/kg
Ca	0.032 W + 2.4 Y gr.	3.5 - 5.5 gr.
P	0.042 W + 1.5 Y gr.	3.0 - 4.0 gr.
Na	7 + 0.5 Y gr.	1.0 - 1.5 gr.
Mg	(2.5 + 0.12 Y) * A gr.	2.0 - 5.0 gr.
K	0.03 W * 2 Y gr.	8.0 gr.
Cl	0.04 + 1,2 Y gr.	3.5 gr.
I (iodine)	+ 0.25 Y mg.	0.6 mg.
Mn	-	25.0 mg
Zn	-	25.0 mg.
Cu	-	10.0 mg.
Vit. A	24,000 + 1,500 Y IU	2,000 - 3500 IU
Vit. D	10 W IU	300 - 500 IU

W = bodyweight in kg;
Y = milk yield p/day in kg;
A = 100 / absorption % (% in grass ~10 %, in maize silage 15-18 %);
gr = gram;
mg = milligram
IU = International Units

6.3 The Need for Nutrients

The nutritional requirements for dairy can be subdivided as follows:

1. Maintenance
2. Production
   → Growth - to reach maturity
   - during lactation to reach majority
   - to improve condition
   → Pregnancy
   → Milk production

6.3.1 Maintenance

Nutrients are used to keep the body in good health and to maintain its temperature without bodyweight gain/loss. Majority of nutrients are used by muscles to:

- pump hundred of litres of blood each day + breath
- squeeze hundreds of kilograms food and water in the digestive system (eating, swallowing, ruminating, contractions, and digestion)
- moving in order to collect the food
- continuously repair of worn-out tissue

The nutrient requirements for maintenance depend on the bodyweight and the feeding system. The bodyweight of an animal can be "measured" by **weighing, measuring** and **observation**.

Weighing balance or weighing bridge. A very accurate method during the growth-period till maturity (fluctuations at maturity depend on condition). Regular weighing will be required to determine the bodyweight and to check if the targeted growth-rate per day is reached. Weighing should be done at least once in 3 months and in order to reduce the chance of bodyweight fluctuations it is advised to carry out the exercise always at the same time of the day e.g. early morning, after feeding (and milking) to avoid stress in the warm climates.

Measuring tape and yard stick. This system gives a reasonably accurate indication of the bodyweight and special of the growth of an animal (gain per day).

Observation and estimation by "eye". It needs a lot of experience to "develop an eye" for correct estimating. It is not reliable for estimation of body weight gain in relation to feed requirements.

Table 6.5: Maintenance Requirements

Live weight (kg)	DM (kg)	FUM (units)	DCP (gram)
400	5.55	3812	290
450	6.06	4112	315
500	6.56	4412	340
550	7.04	4712	365
600	7.52	5013	390
650	7.98	5313	415
700	8.44	5613	440
750	8.89	5913	465

The maintenance requirements mentioned are to be used for "indoor feeding" systems. In yard systems, with frequent handling (milking, weighing, feeding), requires an increase of 10-15%. If the animals are properly housed, no extra nutrients for maintenance will be required during winter time (no direct wind, good ventilation, dry floor with some dry bedding.

6.3.2 Production

Production is divided into **growth, pregnancy** and **milk production**.

The body condition of a cow can be estimated by the "condition-scoring" system. Judgement is based on the appearance of the tail head (fat deposits or lack of it) and indicated by a score from 0-5. Detailed information on the condition-scoring system is given in Appendix 5.

Growth, to reach maturity
Growth allowance depends on the policy of age at first calving (required growth rate per day) and consequently required bodyweight at age of first service.

Special care should be given to the feeding of young stock during the period immediately after weaning. Usually the offered quality of the food is insufficient and calves suffer a severe setback, which may take a long period to recover. Conditions usually improve again at an age of 1 year, when the rumen is sufficiently developed. By that time however, the retarded growth will have a lifelong negative effect on the production capacity of the animal. Special care should be taken not to feed mouldy hay, as this affects rumen development.

Table 6.6: Suggested Target Weights and Daily Growth Rates for Different Ages At First Service and Calving (Hf, 600 Kg At 4 Years)

Age 1st calving	Age 1st service	Target weight at 1st service	Weaning weight at 10 weeks	Days and gain (kg) weaning service		Growth rate/day weaning service	
(month)	(month)	range (kg)	(kg)	days	kg gain	min.	av.
24	15	350-375	70-75	390	275-300	770	800
30	21	400-425	70-75	570	325-350	615	640
36	27	450-475	70-75	755	375-400	530	550

Cont'd

Days and gain during first 7 mths pregnancy (*)			Bodyweight pre-calving (**)	Required growth rate months 7-9	Bodyweight post-calving
(kg)	days	gr/day (kg)		(gram/day)	(kg)
160	215	750	565 – 590	1,000	500-525
135	215	630	590 – 615	1,000	525-550
110	215	515	615 – 640	1,000	550-575

* foetal development is estimated at 20 kg during the first 7 months of pregnancy and includes membranes and foetal fluids
** pre-calving weights include 60-70 kg for calf
*** the growth rates are higher than the actually calculated (minimum) growth rates as to allow for some setbacks during the growth period

Growth allowances during lactation till maturity

In animals calving for the first time at ± 24 months of age, the development of the body continuous. Maturity is normally reached at the end of the second lactation (at an age of ± 4 years). The extra nutrients required for continued growth (growth allowance) till maturity for these animals are:

- during first lactation: 600 FUM and 80 DCP extra per day
- during second lactation: 300 FUM and 40 DCP extra per day

If an animal calves for the first time at 36 months, an extra growth allowance is only required during the first lactation until the animal reaches maturity at 4 years of age. This growth allowance during this first lactation is 10 % of the total maintenance requirement.

The growth allowances during lactation come on top off normal maintenance and production requirements.

Growth to improve condition

Due to the *energy-gap* (negative energy balance) incurred during early stage of lactation, causing loss of condition, requires *regaining of bodyweight*. This loss of bodyweight is to be gained during the middle and late stage of lactation and possibly during the dry period.

A high yielding adult cow is expected to lose 30-60 kg bodyweight during early lactation (1-1½ points in condition score). Efficiency of feed utilization for growth is higher during lactation than during the dry period. The required growth per day for the regain bodyweight losses depends on the policy of the lactation and dry cow feeding management (see Chapter 8).

6.3.2.1 Pregnancy Allowance

It is common to include some extra nutrient allowance during the last two months of pregnancy (months 8 and 9). Fetus development (including fluids and placenta) is ± 20 kg at 7 months, 35 kg at 8 months, and 65-70 kg at 9 months. In lactating cows, this pregnancy-allowance will coincide with the dry period after the previous lactation (last two months before calving). The amount for pregnancy-allowance depends on the condition of a cow after completing her lactation (look at the condition-scoring, maximum allowed condition-scoring target is 3-3½ (see Chapter 8).

General recommendations for nutrient requirements during the last 2 months of pregnancy are:

Condition score at the end of lactation	**Maintenance requirement**
< 3 at end of lactation	
- 8th month pregnancy (1st month dry period)	+ 5 kg of milk production
- 9th month pregnancy (2nd month dry period)	+ 10 kg of milk production
3-3½ → good score	
- 8th month pregnancy (1st month dry period)	+ 2 kg of milk production
- 9th month pregnancy (2nd month dry period)	+ 7 kg of milk production
> 3½	
- restrict feeding, provide exercise	

In advanced dairy management systems, the tendency is to bring animals in a good condition during the last stage of her lactation (more efficient food utilization). If the animal is a first calver (heifer), the total allowance for growth and pregnancy during the last two months of pregnancy should be sufficient for a daily growth of ± 1,000 gram per day.

An animal should not be too fat at calving time (max. condition score 3-3½). Animals that are too fat at calving time will have a poorer performance (at calving and during the following lactation), since they become more susceptible to certain diseases (see Chapter 8.1.2.1-3).

Actual feeding levels for growth and pregnancy are to be decided following close observation of actual performance and condition. The above mentioned figures serve merely as guidelines.

6.3.2.2 Nutrient Requirement for Milk Production

The total amount of nutrients required for milk production depends on the actual or desired amount of milk production in kg/day and on the quality of the produced milk (butterfat %).

The requirement per kg milk with 4 % fat is:

0.37-0.41 kg DM
460 units FUM
63 gram DCP

For each ½ % butterfat more or less, add or subtract 0.065 units FUM and 4 gram DCP per kg of milk.

CHAPTER 7
FORMULATION OF RATIONS

Introduction

The purpose of ration formulation is to provide an animal of nutrients for maintenance and (desired) production. A balanced ration formulates proportions and quantities of nutrients to properly nourish an animal for 24 hours. The economic context is an extra dimension. Decision making is necessary to aim for maximum economic benefit, maximum physical production, or possibly both considering social aspects, such as milk supply for certain target groups or employment. To approach least-cost ration formulation:

1. **Calculate the total nutrient requirements of the animals** (chapter 6);

2. **Determine available ingredients (feedstuffs) and their nutrient contents**: These depend on the local situation and the season. Determine what is possible to feed during winter. A balance is required between energy containing foodstuffs and products with high protein content.

3. **Develop a basic ration of roughage and possibly some concentrates to meet requirements for *maintenance* and *some milk production* (5-8 kg)**: First roughage intake capacity must be fulfilled. If feedstuffs are analyzed, it is possible to calculate the *feeding value*. There might be a shortage in protein.

   Basic ration often does not fulfils the feed requirement for all production: Extra concentrates are needed. Consider the required ratio *energy: protein*, and compose an adequate concentrate.

4. **Match first 3 steps in the formulation, so that ingredients (quality and quantities) fulfil the animals nutrient requirements**;

5. **Match first 3 steps at "least-cost" ration formulation** (paragraph 5.6.3).

7.1 Conditions and Limitations for Ration Formulation

Some conditions and limitations have to be considered for the ration formulation. The main aspects to take into account are:

1. Dry Matter Intake (DMI)
2. Minimum Roughage Intake
3. Required Amount of Energy (FUM)
4. Protein Requirement
5. Limiting Aspects of Certain Feedstuffs
6. Availability
7. Mineral and Vitamin Requirements
8. Selectivity (refusal) and Waste

7.1.1 Dry Matter Intake (DMI)

The required nutrients must be available in the quantity of DM an animal is able to consume within 24 hours. If not, a ration is not considered balanced. In practice, the maximum DMI from roughage is not more than 2% of the body-weight. Paragraph 6.2.2 explains how to calculate the expected DMI, based on bodyweight and production.

7.1.2 Minimum Roughage Intake

To avoid disturbances in functioning of the rumen, metabolic disorders and to maintaining a high butterfat level in the milk, **at least** 30% of the total DM in the ration should be supplied by roughage. In case high quantities of young roughage are supplied (young grass, grass and maize silage) the structure value of the ration is to be considered (see paragraph 3.3 and Appendix 3).

7.1.3 Required Amount of Energy (FUM)

Under all conditions the required quantity of FUM should be supplied. In an energy-deficient ration, the animal will utilize proteins as energy.

First priority in dairy feeding is to fulfil the demand for energy. During early lactation, from calving till end of peak yield (see Chapter 8), DMI is limited (energy gap). A cow will mobilize her body-fats to fulfil the demand for energy, provided that sufficient extra protein is made available to her during this period.

7.1.4 Protein Requirements

In the protein requirements, four aspects are to be considered:

1. "Normal" protein requirements
2. Protein : energy ratio
3. Protein-demand during early lactation from calving till end of peak yield
4. Quality of the proteins degradability

7.1.4.1 "Normal" Protein Requirements

Although desirable, it is not always necessary to cover quantities of required proteins completely within a ration (provided the energy demand is completely covered). The protein may be 5-10% lower than the calculated protein. Under "*normal*" is understood low and medium production levels, dry periods, and in case of a slow growth rate requirements to reach the aimed bodyweight at first service.

Anyhow, a slight "under-feeding" in protein (below requirement) is tolerated. The condition and development of an animal is to be considered first of all.

7.1.4.2 Energy: Protein Ratio

The ration *energy: protein* becomes more narrow with increasing production (Chapter 5.1). Animals with a high milk production will require concentrates with a higher energy percentage than animals with a low milk production. For example, a energy: protein ratio (FUM : DCP) for **maintenance + 5 kg milk** is 1 : 12.1. For **maintenance + 40 kg milk** this is 1 : 8.2. The DCP level decreases with ± 30%!

As protein is expensive, it seems desirable (economical) to have different types of concentrates available for the requirements of the different livestock classes: high yielding, medium yielding, low yielding/dry period, as experienced through the different stages of lactation.

7.1.4.3 Protein-demand During Early Lactation From Calving - End of Peak Yield

The cow experiences a depressed appetite during the early lactation period (first 8-12 weeks). During this period the cow is experiencing an "energy-gap", which she will fill by mobilizing her body reserves (fats), provided she had a sufficient good condition at calving (condition-score 3-3½). See for details Chapter 8.

Also a "protein-gap" is experienced. The cow lacks the means to mobilize the required proteins from her body reserves. To enable a cow to mobilize her body reserves (fats) as to reach a maximum peak yield (and lactation yield!) the protein requirements have to be increased by 10-15% during this period. All required proteins are to be squeezed in the DM a cow can eat at that moment. It seems appropriate to have a special high protein concentrate mixture available for this early lactation period, if maximum peak yield and subsequently maximum lactation yield are to be reached.

7.1.4.4 Quality of the Proteins Degradability

As indicated in Chapter 2.3.3, the protein requirements over 13% CP (which is ± 8½ % DCP as DCP = 0.65 x CP) have to be met by **undegradable** proteins, also "*by-pass*" proteins. These are playing an important role in fulfilling the protein demands for a high milk production. The role becomes more important in rations containing high amounts of good quality grass silage or young grass, as these contain low amounts of undegradable proteins (see Appendix 1).

7.1.5 Limiting Aspects of Certain Feedstuffs

Some feedstuffs contain substances/toxins, which may limit their use (molasses → diarrhoea, cotton seed → gossypol, some cakes → high fat-contents, brassica products → goitrogenic products) or contain substances influencing, e.g. taste of the milk (fish meal → taste in milk), and therefore only limited amounts can be mixed in the ration. Paragraph 5.4 notifies the maximum amounts of ingredients that can be used in concentrate mixtures used in rations in which more than 50% of the total ration DM is supplied by concentrates.

7.1.6 Availability

Continuity of supply may be considered, when a certain ingredient is included in the formulation of the ration.

7.1.7 Required Minerals and Vitamins

These aspects are not considered in the formulation of a ration. However, minerals and vitamins can be included in the concentrates (2-3% when NaCl is provided ad lib), the amounts and composition depending on the calculated needs / deficiencies. When high amounts of concentrates are fed one may consider to add some extra concentrates to cater for the nutrient value "occupied" by the minerals in the concentrates.

Example
10 kg of concentrates carries 300 gram of minerals. Nutrients are probably calculated for. One may add 0.25 kg of concentrates to balance the "calculation-gap" in FUM and DCP.

7.1.8 Selectivity (Refusal) and Waste

In order to allow for selective intake from roughage, the quantity of roughage offered should be more than calculations made. Depending on quality, the "refusal" (the quantity not eaten on a voluntary basis) may be as high as 35 % of the amount fed to the animal. Chopping roughage below 10 cm will reduce selectivity. The overall digestibility of roughage will be reduced, demanding more quality and quantity of concentrates to balance the requirements.

Within a zero-grazing system an allowance of 10-35% of extra roughage has to be considered to allow the selective intake by the animal (percentages may vary per type of roughage). Waste is the quantity of roughage spilled on the ground/floor and trampled and thus not fit any more for animal consumption (really a waste).

Losses by waste can be reduced by: proper feed-trough / feed-rack design, sufficient space per animal at the manger, chopping roughage to 20-25 cm (does not affect selectivity) and dehorning (in yards, animals become less "bossy"). Allowances for refusal and waste can be determined by observation (and weighing, consider extra weight from moisture/dirt).

Note: *It should be realized that the overall DMI and total nutrient requirements of an (individual) animal are not affected by the above mentioned aspects. Advise is to offer more roughage than the calculated requirements.*

CHAPTER 8
FEEDING POLICY AND STRATEGY

Introduction

The impression might be given that feeding should be adjusted according to daily requirements for maintenance and production (as to outline ration formulation discussed in Chapter 7 based on nutrient requirements in Chapter 6). However, a cow does not divide nutrients on daily basis for maintenance and production as used in the ration formulation. Her production is much more a reflection of the overall feeding management during her whole life:

- **Rearing period**: to guide development of production potential within the genetic limitations (selection);

- **Productive period:** to apply a feeding strategy in order to exploit potential milk production covering a complete lactation period, covering:
  → the dry period (the last stage of pregnancy and condition at calving)
  → the early lactation (from calving till the end of "*peak*" yield)
  → the mid- and late lactation stage

The feeding policy should **not** be based on a *static approach* (feeding according to the production on a day-basis), but on a *dynamic approach*. A lifelong feeding policy based on the exploitation of the genetic production potential or aiming for the maximum economic production is the best approach. It can not be expected that the actual production reflects the feeding level of that specific moment.

Animals of different ages, production levels, sizes and conditions vary in their nutrient requirements, being the subject of this chapter.

8.1 Feeding Strategy for Different Classes of Cattle

8.1.1 Young Stock

Generally, the pre-weaning period is the most critical time of an animals' life, usually expensive due to the high costs of milk and high quality concentrates. Calves require a lot of attention during this period. After weaning, rearing gets less critical, but calves should to no account be neglected. To allow animals to produce to their full genetic potential when mature, it must be correctly fed and well cared for during the period between birth and first calving. Management, however, can vary within certain limits and is influenced by the "choice" of target dates for first calving and consequently for first insemination. This choice determines the required daily growth rates during each stage in rearing.

Growth of young stock can be distinguished in two types:

- **Development growth**
  The increase in size of vital parts of the body such as organs/bones and the development of the rumen. Retarded growth and development cannot be compensated at a later stage, thus having a life-long negative effect.

- **Condition growth**
  Necessary to give an animal sufficient body reserves, essential for attaining high production levels after calving.

Development growth is indicated by the size and shape of the body. Condition growth is indicated by the amount of fat, deposited in the body and "measured" by the body-condition scoring method as described in Appendix 5.

Unfortunately, feeding and management of calves after weaning often does not receive enough attention (poor quality roughage, little concentrate, poor housing conditions), resulting in a setback and low growth rates during the first year of life. In the second year the calf may recover, but is not likely to reach optimal development which will be reflected in her productive life by lower milk yields.

Paragraph 6.3.2.1 indicates the nutrient requirements for young stock (after weaning) for three different ages of first calving and first service. Allowances for growth during first and possibly second lactation have also been given, while pregnancy allowances for first calving heifers are present in Chapter 6.3.2.2. The choice whether first calving should take place at an age of 24, 30 or 36 months depends on economic aspects, feed availability and management.

8.1.2 Dairy Cows

From a nutritional point of view, the lactation cycle is divided into 3 periods:

1. Dry period
2. Early lactation
3. Mid- and late lactation.

With a calving interval of about one year, the first 3 months after calving the cow is not pregnant and has a "peak" production. Then, after 90 days, she should be pregnant and continue milk production till month 10 after calving, leaving a dry period of two months before the next calving. In high yielding cows, the calving interval and therefore the lactation period, may be somewhat longer, due to a negative energy balance in the first stage of lactation.

8.1.2.1 Feeding of A Dry and Pregnant Cow

Because a cow is without milk production during the dry period, feeding is sometimes neglected. Nevertheless it is of enormous importance that the animal is in a good condition (not too fat!) at the time of calving as to obtain maximum production level during the early stage of lactation. One should aim for a maximal condition score of 3-3½ (see appendix 5).

It is recommended to restrict feeding (withhold concentrates) one day prior to the date of drying-off, as this will reduce milk production and decreases the risk of mastitis.

The dry period should be used to allow an animal to recover from the previous lactation (if necessary) and to form sufficient body reserves for the next one. Level of nutrition during the pre-calving period depends on following 3 factors:

1. Overall nutrition level related to production during lactation
2. The length of the dry period
3. Demands of the cow in calf and just before calving

Overall Nutrition Level Related to Production During Lactation
At the moment of calving the condition of the cow should be good. A pregnant cow in poor condition at the end of the lactation needs more food during the dry period than a cow already in a good condition. High yielding cows can be expected to repeat that performance during the next lactation, provided they are given the opportunity to replenish their body reserves before calving.

First calving heifers should attain the growth rates as indicated in paragraph 6.3.2, to allow for growth and pregnancy. The recommended growth rate during the last two months of pregnancy is given as 1,000 gram/day. First cows calving should reach a good condition at calving (score 3-3½), which may influence the feeding management of heifers.

The Length of the Dry Period
It is generally recommended to have a dry period of two months for animals still producing substantial quantities of milk at the scheduled date of drying-off, but also for animals with lower productions and/or longer calving intervals. A long dry period appears, for biological reasons, to have a negative residual (carry-over) effect into the next lactation. Cows with a long dry period most likely lack so-called "dairy merit", or milk production potential and tend to become too fat. One should very carefully watch the condition and feeding may have to be restricted and exercise provided to facilitate calving.

Demands of the Cow in Calf and Just Before Calving
During the last two months of pregnancy the uterus and the calf develop rapidly (the total gain is 40-50 kg in this period). Feed requirements depend on the condition of the animal. The requirements for pregnancy itself are:

8th month (1st dry month):	as for production of 2 - 5 kg milk
9th month (2nd dry month):	as for production of 5 - 10 kg milk

Live weight-gain during late pregnancy should be about 500 gram/day or about 300 gram/day for animals in good condition. Recommended feeding levels for pregnancy are given in paragraph 6.3.2.1. Usually no extra pregnancy allowances are recommended during the first 7 months of pregnancy.

The present tendency is to bring animals in good condition during the late stage of lactation, as apparently the development of body reserves during lactation is much more efficient than during the dry period. The old approach of "*steaming up*", giving extra concentrates during the last 3-5 weeks before calving, is now considered to have negative effects by having animals too fat at time of calving. Bringing the cow in a too fat condition before calving is costly and has many negative effects on health and production capacity of the cow.

A (too) fat condition at calving time should be avoided, as this may have the following consequences:

1. Difficult birth
2. Lower feed intakes
   → Large scale mobilization of body fat reserves: "*Fat Cow Syndrome*"
   → Acetonaemia or "*Liver ketosis*"
   → *Acidosis*, and as a consequence *laminitis*
3. Diseases like retained placenta and metritis
4. Oedematic conditions
5. Milk fever

Difficult birth
Fat-deposits in the birth-path increase the possibility of difficulties at birth and possibly weak calves.

Lower feed intakes
A fat cow **eats less** and thus reduces her energy intake during early lactation. This may lead to:

- Large scale mobilization of body fat reserves to compensate for the lack of available energy. As the liver may not be able to cope with large amounts of fats, liver-cells will be damaged or killed. Others will lose their functional capacity as they fill up with fat. This malfunction of the liver is known as "*Fat Cow Syndrome*" or "*Fat Liver Syndrome*" and may cause a cow to be depressed, with reduced appetite and possibly death.

- A disease associated with the "Fat Liver Syndrome" is *acetonaemia* or "*Liver ketosis*". The mobilization of fats due to shortage of energy results in production of ketones, which in large quantities are poisonous. A cow with ketosis in early lactation will become dull and lethargic, loses appetite, refuses concentrates and possibly roughage which aggravates the condition of ketosis since it was caused by lack of energy. Many mild cases of ketosis may go unnoticed. They are self-limiting as milk production may decrease to a level at which the energy balance is more or less restored. Some cases may become chronic. Ketosis seldom kills a cow, but it ruins productivity for the rest of the lactation (low peak yield and low lactation yield).

- *Acidosis*, and as a consequence *laminitis*, are also associated with mobilization of large amount of body fat reserves caused by low intake of energy by a (too) fat cow. Breakdown of body fats may lower the rumen pH as result of increased production of propionic acid from the fats.

Retained placenta and metritis
Diseases like *retained placenta* and *metritis* are associated with problems related to difficult births and lower feed intakes, leading to a lower fertility status.

Oedematic conditions
Overfeeding may cause oedematic conditions during the last stage of pregnancy. It possible cause for a more pendulous udder, as the suspension ligaments may become weakened due to the heavy udder.

Milk fever
Milk fever is another serious disease which may be associated with a too fat body condition at calving (although not necessarily). Concentrate supplements in late pregnancy may have a severe negative effect on the mineral resorption, particularly Calcium (Ca), from the gastro-intestinal tract. The daily requirement of Ca varies according production level. Ca requirements are higher during lactation as the cow excretes Ca in the milk. During the dry period, the daily need for Ca is much smaller. This has two major effects in the cow:

→	the resorption of Ca from the intestines slows down to a very low level
→	the resorbed Ca, not required for maintenance and fetal growth, is being deposited in the skeleton as reserves.

The skeleton plays an important role in the metabolism of some minerals, particularly Ca. During peak demands (high milk production), the skeleton releases minerals into the circulation and in time of abundant supply it can store the excess. Supplements of (extra) concentrates, containing "natural" and supplemented minerals, strengthens the process of further reduction in resorption and more deposits in the skeleton. At calving, a cow suddenly meets a very high demand for Ca, as large amounts are being secreted into the colostrum. This causes a sudden drastic lowering of Ca-levels in the blood, resulting in the acute occurrence of milk fever (hypocalcaemia) and its complications.

The low level of Ca in the blood triggers off various processes in the body, of which the most important are:

→	Rapid increase of resorption capacity of Ca from the intestines
→	Reversal of the process of depositing Ca, to again the release of Ca from the skeleton into the bloodstream

However, it takes some time before these processes are adjusted again to the situation of milk production and consequently the high(er) needs for Ca. It is therefore advised, to reduce or withhold Ca during the last 7-10 days of the dry period as to force the animal at this stage already to reverse the process of deposit of Ca into the skeleton to releasing the Ca from the skeleton in the blood and to increase the resorption capacity of Ca from the intestines. The supplementation of Ca to be resumed again on the day of calving to increase the Ca in the blood-levels during the early lactation and thus reduce the chance of milk fever. Milk fever is usually also associated with retained placenta and a reduced fertility status.

Conclusion
Overfeeding during the last month of pregnancy is costly in terms of money, potential production performance, health and fertility during the early lactation and subsequently affects the total lactation performance. It is wiser to save on concentrates during the dry period, preventing an animal from becoming too fat and spend extra money on concentrates during the period of early lactation as to "guide" the cow to a high peak yield (and thus a high lactation yield).

Underfeeding during the dry period (condition score below 3) will result in a low yield during the next lactation. This can not be corrected any more during the lactation period. Requirements for peak milk yield are already in excess due to intake capacity. Underfeeding or unbalanced feeding can also disrupt the breeding cycle (lowered fertility status during early lactation) and influence the health of an animal, both directly and indirectly, by reducing its resistance against infections and stress.

A lower peak yield will result in a lower lactation yield, as will be discussed later in this chapter. The aim is to reach a body condition score of 3-3½ at calving for maximum health, production and fertility status.

8.1.2.2 Feeding During Early Lactation (Calving - Peak Yield)

The pattern of milk production corresponds to the pattern of milk requirements of the calf. A rapid build-up in yield at the start of lactation corresponds to the rapidly increasing demand by the calf. The fall in production from peak yield corresponds to an increased ability of the calf to consume forages and other feeds, developing its ruminant characteristics.

The physiological drive of a cow to produce milk is strongest in early lactation due to the biological reasons. Feeding during this period is important. As the drive to produce milk declines when lactation advances, relatively more food will be used for increasing live weight gain. Therefore, feeding should encourage milk production when it is most easily stimulated: during the period from calving till reaching the peak yield at about 5-6 weeks after calving.

Pre- and post calving feeding affects the peak yield. Improved milk yield in the early lactation is associated with a proportionally greater partition of nutrients towards milk at the "expense" of body reserves, which have to be restored during mid- and late lactation.

The DMI is usually very much reduced (depressed appetite) just before and immediately after calving and is perhaps only 45-50% of the "normal" DMI. Appetite after calving recovers gradually, reaching full level at about 10-12 weeks after calving (just after peak yield level, when the production starts to decline).

DMI at calving may reach 1½ % of the bodyweight, while reaching 3-3½ % of the bodyweight at 10-12 weeks after calving. Some animals even may reach a DMI of 4% of the bodyweight. During the period when appetite is low, the animal is experiencing an "*appetite-gap*" resulting in an "*energy-gap*" as milk production is higher than DMI.

To meet the energy demand of the rising production the cow will mobilize her body-reserves, which were stored during the later stage of previous lactation and dry period (score 3-3½). By mobilizing her body reserves (or "*milking off the back*"), the cow enables herself to reach maximum peak yield.

The currently advised feeding regime during the last month of pregnancy with ad lib roughage feeding is:

-	day 1-7 post-calving:	increase concentrate gift by 1.0 kg/day
-	day 8-20 post-calving:	increase concentrate gift by 0.5 kg/day

The aim is to try to increase the DMI as much as possible as to reach the highest possible peak yield and lactation yield. During the period of the "energy-gap" the first 10-12 weeks, the animal mobilizes her body-reserves. In order to "assist" the cow in an efficient mobilization and utilization of body reserves, a concentrate with a higher protein content (of 10-15% above the calculated production requirements) is required.

Supplementation of concentrates with good quality roughage has the greatest effect on milk production when the cow is in early lactation and has a high genetic potential. The total response over the whole lactation can be 3-5 times higher than the immediate response during the first two months of the lactation, due to the residual effect of the supplementation.

High yielding cows have a better response than low yielding cows to supplements, which is shown by following experiment in table 8.1.

Table 8.1 Response to 1 kg of supplement of concentrates

	Short term effect	**Long term effect**
High yielder	1.6 kg milk/day	3.7 kg milk/day
Low yielder	0.2 kg milk/day	1.5 kg milk/day

High yielding adult cows are expected to loose 35-55 kg of their bodyweight during the first period of lactation (50-70 days). This corresponds to a drop of 1-1½ points in condition score. In heifers, a loss of 15-25 kg is equivalent to a 1 point drop in condition score. Losses greater than indicated usually mean under- feeding or a (chronic) disease.

If a cow starts to gain considerable weight or condition during early lactation, it is likely that she is expressing her milk production potential and that her potential is not very high.

Some important aspects of early lactation are:

- peak yield
- prediction of lactation yield
- fertility status

Importance to reach peak yield
The level of possible production in mid- and late lactation is decided by the level of peak yield, which itself depends on:

- potential of the animal
- body condition at calving
- level of feeding during early lactation

Good feeding in early lactation can be expected to produce a long-term effect (on mid- and late lactation) and improve total milk yield. It favours the distribution of nutrients towards milk production rather than weight gain, and leads to a more persistent and flatter lactation curve.

If the peak yield is depressed, the loss can not be recovered during the later stages of lactation. Depressed peak yields can be caused by:

- Too fat condition at calving and its consequences
- Insufficient feeding and a poor condition at calving
- Diseases associated with nutrition and hygiene
- Mastitis
- Interruptions in feeding or sudden changes in ration
- Stress, such as handling, transport and weather changes
- Faulty milking techniques and/or machinery

Prediction of lactation yield
The pattern of lactation is being established during early lactation. The milk yield rises to a peak at ± week 5 of lactation, persists for ± 3-4 weeks and then begins a slow decline. Assuming the cow has been successfully inseminated ± 90 days post partum, the hormonal changes associated with pregnancy will then accelerate the decline in milk yield to the point of drying-off, after a lactation period of ± 305 days. With the peak yield, the expected lactation yield can be predicted. As a rule of the thump, the peak yield is ± 0.56% of the total lactation yield.

For example:

Peak yield in kg/day	Estimated total yield in kg (305 days)
10	10 x 0.56 x 305 = 1,708
20	10 x 0.56 x 305 = 3,416
30	10 x 0.56 x 305 = 5,124
40	10 x 0.56 x 305 = 6,832
50	10 x 0.56 x 305 = 8,540

Moreover, one can also anticipate that decline in yield after 70-90 days is about 1½-2% per week. If the decline is too rapid and the total yield does not meet expectations based on peak yield, than something is wrong. Either in nutrition or because of health problems. If the rate of decline after 90 days is less than 1% this suggests either that the cow is not pregnant, or that peak yield was not as high as it might have been. The following points should be kept in mind:

- Rules mentioned apply for temperate breeds, kept under temperate climatic conditions. In warmer climates the decline of milk yield may be less persistent (e.g. 3% decline/week) due to the poorer food quality and heat stress.

- High yielding cows usually have a more persistent lactation curve than low yielding cows.

- When judging the persistency of lactation, one should consider whether the low persistency is the problem of an individual cow or of the total herd. The latter indicates management or environmental constraints.

- Properly kept milk records are essential and the basis for good management and identification.

The consequences of a lower peak yield are quite severe. A reduction of 1 kg milk/day in peak yield may result in a lower total yield of 200 kg.

Another method of predicting lactation yield is by multiplying the starting yield (= average daily production in the first month) by 200.

Early lactation and fertility
It is a known fact that the fertility status is reduced during periods of weight loss. When the average condition score falls below 2, fewer cows will come in oestrus and the conception rates of those cows coming in heat will be about 50%. Weight gain has a positive effect on oestrus and conception.

There may be an energy-gap and a corresponding period of weight loss during the first 8-12 weeks of lactation, which will negatively influence fertility. During this period it is advised to practice "*lead-feeding*", feeding ± 10-20% above nutrient requirements, as to challenge the production level and also to reach as soon as possible the stage of weight gain in order to enhance fertility. Lead-feeding should continue till a cow is pregnant again, provided the conditions are normal.

In very high yielding animals, the time that the energy balance turns positive could reach at 10-12 weeks after calving. Therefore, the average conception may not take place until 100-120 days after calving, increasing the lactation period to 320-340 days. This is the price which has to be paid for high yields and is no cause for concern. If pregnancy is delayed because of under- or over feeding during the dry period or the hygienic conditions, then management needs improvement.

8.1.2.3 Feeding During Mid- and Late Lactation

In mid lactation, between 12-20 weeks after calving, nutrient requirements for milk production are less pronounced. As a result, extra feed is partially converted into extra milk and partly for recovery of bodyweight. The response to extra feed, in terms of milk production, decreases as lactation progresses.

During this period, it is not justified to increase the feeding level of an animal with a low or decreased peak yield in the hope of still making them high a yielder. Although a small improvement may be obtained, most of the extra nutrients will be utilized for weight gain. Response in milk production to extra concentrates is closely linked to current yield. The immediate effect per extra kg of concentrate is twice as high for a cow producing 30 kg of milk/day as for a cow producing 15 kg of milk/day.

Depending on the body score at the end of the early lactation period the aim should be to allow the animal to regain weight of 100-200 gram/day. The quantity of concentrates should be adjusted for the reached peak yield and expected decline in production, allowing some nutrients for regaining bodyweight. In no way should feeding be based on calculated production requirements only, as this will reduce the actual production.

The quality of concentrates can also be adjusted, as the extra DCP allowance of 10-15% for mobilizing the body reserves is not required any more.

During late lactation (from 20 weeks post partum till the end of the lactation) the quantity and quality of supplementary feeding may be adjusted again, although advanced production systems will allow the animal to regain more bodyweight, till may be reaching a condition score of 3 at the end of lactation. Apparently food conversion efficiency towards weight gain is higher during lactation than in the dry period. The quality of the concentrate may be adjusted as the lower yields will lead to a wider DCP-FUM ratio. Efficiency of food conversion into milk tends to be constant during the lactation cycle, but at all levels of DMI the potentially high yielding cow directs more nutrients to milk and less to body reserves than the lower yielding animal.

8.2 Summary

The "phases of lactation" can be summarized as follows:

- **Dry period**
  Bringing the animal in good condition (2 months) to reach maximum body score of 3-3½ at calving as to have sufficient body reserves during early lactation.

- **Early lactation**
  Development of milk production-potential as (2½-3 months) expressed by the peak yield (lead-feeding).

- **Mid-late lactation**
  Exploitation of milk production potential (7-7½ months), recovery from early lactation and preparation for next lactation by restoring body reserves.

Amounts and quality of concentrate are to be adjusted during the different periods of lactation, but in no way should the animal be allowed to become too fat, nor should management "economize" too much (reduce supplementary feeding according to actual production) in mid and late lactation leading to a "pulling down" of production. Especially during early lactation, one has to be careful that at least 30% of the total ration is supplied in the form of roughage. Protein levels in concentrates are of special concern during the different stages of lactation. Consider 10-15% extra DCP during early lactation and widening the DCP-FUM ratio during the later stages of lactation cycle, including the dry period.

LIST OF ABBREVIATIONS

Ad Lib	Ad libitum.
Diet	A particular combination of feedstuffs fed to an animal, eg. a diet consisting out of hay, maizesilage, wheatbran and soyacake.
Food	A material which, after ingestion by animals, is capable of being digested, absorbed and utilized. However, in a more general sense the term "food" is used in this paper to describe edible material. Other terms used are: feedstuff(s), animal feed, feeding materials.
Ingredient	Describes a particular product, like maizemeal, wheatbran, etc., as a part of a concentrate (mixture).
Nutrients	Are those components capable of being utilized by animal.
Ration	The quantity of the diet fed within 24 hours to a particular animal (or group of animals).

DCP	Digestible Crude Protein
DCF	Digestible Crude Fibre
DM	Dry Matter
DMI	Dry Matter Intake
DNFE	Digestible Nitrogen-Free Energy
DCEE	Digestible Crude Ether Extract
CF Crude Fibre	
CP Crude Protein	
DCP	Digestible Crude Protein
DE Digestable Energy	
EE Ether Extract	
FUM	Feeding Unit for Milkproduction: units of energy for producing milk
GE Gross Energy	
HF Holstein Friesian	
IOM	In Organic Matter
ME	Metabolizible Energy
NE Nett Energy	
NEG	Nett Energy Growth
NEL	Nett Energy Lactation
NEM	Nett Energy Maintenance
NFE	Nitrogen Free Extract
NPN	Non Protein Nitrogen
OM	Organic Matter
RMO	Rumen Micro Organisms
SE Starch Equivalent;	Nett Energy
TDN	Total Digestable Energy
VFA's	Volatile Fatty Acids
WW II	Worldwar II

gr	gram
kg	kilogram
kg FCM	kilogram Full Cream Milk
ha	hectare
l	litre

Elements

Na	sodium
Ca	calcium
N	nitrogen
P	phosphorus
Cl	chlorine
K	potassium
S	sulphur
I	iodine
Mn	manganese
F	fluorine
Co	cobalt
Mo	molybdenum
B	boron
Cu	copper
Zn	zinc
Mg	magnesium
Fe	iron