Measurement of energy and protein requirements

- In evaluating nutritional requirements of animals, maintenance is the benchmark because this is when nutritional needs are lowest promoting zero balance
- The purpose of a maintenance ration is to prevent drain on the body tissue
- Animals deprived of food are forced to draw upon their body fat reserves to meet their nutrient requirements (i.e., Milking away from the back)
- Severely fasted animals must oxidise reserves of nutrients especially fats to provide energy needed for such essential processes as respiration and circulation of blood. In the processes, acetyl COA accumulates as a result of β-oxidation. The process of ketogenesis takes place in mitochondrial matrix of liver cells when the carbohydrate supply is very scarce (i.e., when energy is produced by breakdown of fatty acids). Due to presence of high levels of Acetyl CoA from β-oxidation, pyruvate dehydrogenase complex is inhibited . As a result, citric acid cycle is inhibited and pyruvate carboxylase becomes activated and the excess of Acetyl CoA is directed towards ketogenesis (See notes of ANS 2104).
- This may be characterised by formation of ketone bodies such as Acetone, acetoacetate, β-hydroxybutyrate
- Due to inefficiencies of chemical energy conversion, some of the energy leave the body as heat energy, leading to a state of negative energy balance if exact animal nutrient requirement instead of allowance is provided for maintenance
- The maintenance requirement of a nutrient can therefore be defined as the quantity which must be supplied in the diet so that the animal experiences neither net gain nor net loss of that nutrient
- Farm animals are rarely kept in this non productive maintenance state but this requirement is of significant importance particularly in dairy cattle since total requirement is arrived at in a factorial manner by summing up requirements calculated separately for maintenance and production
- In the factorial method, the nutrient requirement for each relevant metabolic function is calculated separately and then these are summed up.
- For example $ME = NE_L + NE_m + H_iE + Fe + Ue$

where ME = Total metabolisable energy required in the feed

NE_L= Net energy retained in the products like meat or milk

NEm= Net energy required for maintenance

HiE = Heat increment

Fe Faecal energy

Urinary energy

- ME (MJ/ kg DM) of a feed can be calculated from the proximate analysis of the feed as follows:

Ruminants

- ME (MJ/ kg DM) = 11.78 + 0.00654CP + 0.000665EE^2+ 0.00414EE*CF-0.0118TA
- ME (MJ/ kg DM) = 0.016DOM where DOM is the digestible organic matter
- ME (MJ/ kg DM) is sometimes referred to as M/D or energy density of a diet

Poultry

- Apparent ME (MJ/ kg DM) = 0.034EE + 0.0165CP+ 0.0172STA + 0.0158SUG

Pigs

- DE (MJ/ kg DM) = 17.38 + 0.0105CP + 0.0114EE – 0.0317CF – 0.0402TA

Where EE = Ether extract, CP = Crude protein, STA = Starch, SUG = Sugar, CF = Crude fibre, TA = Total Ash (All expressed as g/kg DM)

Protein requirement in dairy cattle from a feeding standard table

Metabolic function	Requirement
1) – Growth	10 g P/kg of body weight gain in calves
	5 g P/kg body weight gain (Adults)
2 – Pregnancy (Reproduction)	0 g P/day (At conception)
	0.4 g P/day (Mid-term)
	4 g P/day (Full-Term)
3 – Lactation	1.7 g P/kg of Milk produced
4 – Endogenous losses (EUN, MFN)	0.6 g P/day (at Birth)
	6 g P/day (at 250 Kg)
	14 g P/day (Adults)
5 – Availability of P (expressed as K or Efficiency)	90% (at birth)
	65% (at 250 kg)
	55% (When adult)

Derived parameters to predict energy retention

- K_m = efficiency of utilisation of dietary ME for maintenance
- K_L = efficiency of utilisation of dietary ME for milk production

- K_f = efficiency of utilisation of dietary ME for weight gain

$K_m = 0.35q_m + 0.503$

$K_l = 0.35q_m + 0.420$ or $K_l = 0.019$ M/D + 0.420

$K_f = 0.78q_m + 0.006$

- Where q_m is metabolisability of gross energy (GE) at maintenance = [ME]/[GE] and M/D is concentration of ME in MJ/kg DM
- GE of feeds can be estimated from proximate fractions
- GE (MJ/kg DM) = 0.0226CP +0.0407EE + 0.0192CF + 0.0177NFE in which CP, EE and NFE are expressed in g/kg DM.
- When neither calorimetric nor compositional data is available, silage can be allocated GE value of 19.2 MJ/kg DM, high oil compound food 19.4 MJ/kg DM and all other foods a value of 18.4 MJ/kg DM
- It is therefore common in deriving energy allowance to assume that the gross energy value of dry matter of all food is constant at 18.4 MJ/kg DM
- The range of energy concentration in diets for milk production is narrow , therefore q_m for milk production is also widely held at a single factor of 0.62
- Required ME for MP = $\dfrac{\text{Energy value of milk } (EV_L) = NEL}{\text{Efficiency of utilisation of dietary ME for milk production}}$

Required ME for milk production (MJ/day) = $\dfrac{NE_L}{K_L}$

Energy value of Lactation = $EV_L = NE_L = 1.509 + 0.0406F$

Where F = fat content of milk g/kg

NE_L can also be calculated from 4% FCM as NE_L (MCal /kg) = 0.749 * FCM, therefore,

NE_L (MJ/kg) = 0.749*4.184*FCM

Where 4% FCM = 0.4(MY)+(15(MY*(Fat%))

Metabolisable energy requirement for maintenance MJ/Day is calculated as

$\dfrac{\text{Net energy of maintenance } NE_m}{\text{Efficiency of utilisation of dietary ME for maintenance}}$

NE m (MJ/kg) = $0.53\,(W/1.08)^{0.67} + 0.0091W$

$= \dfrac{0.53\,(W/1.08)^{0.67} + 0.0091W}{K_m = 0.35q_m + 0.503} = \dfrac{NE_m}{K_m}$

Example

Use the table below to calculate q_m, K_m and K_f of the steer diet

Diet ingredient	Quantity kg	ME MJ/kg DM	MJ/day
Maize	2	14	28
Hay	4	8	32
Total	6	SUMPRODUCT/6= 10	60

q_m = [ME]/[GE] = 10/18.4 = 0.54

$K_m = 0.35q_m + 0.503 = 0.35*0.54 + 0.503 = 0.692$

$K_f = 0.78q_m + 0.006 = 0.78* 0.54 + 0.006 = 0.427$.

If the net daily maintenance requirement of the steer is 23 MJ NE_m, then its ME requirement for maintenance is calculated as:

$$\text{ME Requirement} = \frac{NE_m}{K_m} = \frac{23.00}{0.692} = 33 \text{ MJ ME/d}$$

ME not required for maintenance = 60 MJ – 33 = 27 MJ

Of the 27 MJ ME, the amount of Net energy that is used for fattening is

27 * 0.427 = 11.5 MJ NE_f/d

This is the net energy retained by the steer as energy of live-weight gain

If the energy content of live-weight gain of the steer is 15MJ/kg of body weight gain per day, then weight gain of the steer can be predicted be

$$= \frac{\text{Available net energy for fattening}}{\text{Energy content of live-weight gain per kg BW gain per day}}$$

$$= \frac{11.5}{15.0} = 0.77\text{kg/day} = 770 \text{ g/d}$$

Example of factorial estimation of ME allowance

Use factorial procedure to calculate the combined metabolisable energy allowance for a 600 kg cow producing 30 kg/day of milk containing 40 g fat/ kg and losing 0.4 kg live-weight /day on a diet with $q_m = 0.6$. Assume that the efficiency of utilisation of mobilised tissue for lactation (K_g) =0.84 and energy value of weight gain is 26 MJ/kg.

Solution:

- This requires us to calculate the metabolisable energy requirement for maintenance and production designated M_{mp} in MJ/day

- This can be got by knowing the ME requirement for both lactation ME_L and maintenance ME_m ie., $ME_{mp} = (ME_L + ME_m)$*Correction factor for level of feeding
- The exact amount of ME requirement got can then be increased by 5% in order to get the allowance as tabulated below:

Parameter	Formula	Formula value
$NE_m = E_m$	$0.53(W/1.08)^{0.67}+0.009W$	$0.53(600/1.08)^{0.67}+0.009*600 = 42.04$ MJ/d
K_m	$0.35q_m + 0.503$	0.35*0.6 + 0.503 = 0.713
$NE_L = E_L = EV_L$	1.509 + 0.0406F (g/kg)	30(1.509 + 0.0406*40) = 93.99 MJ/d
K_L	$0.35q_m + 0.42$	0.35*0.6 + 0.42 = 0.630
Net energy of weight loss during lactation E_g	Change in weight* energy value of weight change/kg	-0.4 * 26 = -10.4 MJ/d
Net energy spared by weight loss	10.4 * efficiency of utilisation of mobilised body tissue	-10.4 * 0.84 = - 8.74 MJ/d
Required ME for maintenance M_m	NE_m/ K_m	42.04/0.713 = 58.96 MJ/d
Required ME for Lactation M_L	(NE_L+ energy spared by weight loss)/ K_L	(93.99 -8.74)/0.630 = 135.32 MJ/d
Level of feeding (L) Correction factor for the combined maintenance and lactation	$(1 + 0.018 (ME_p/ME_m))$ M_p = ME energy requirement for production = M_L M_m = ME energy requirement for maintenance = M_m	$(1 + 0.018 (M_p/M_m))$ L = (1 + 0.018 (135.32/58.96)) = 1.041
Required ME for both maintenance	$(M_p + M_m)$ * Level of feeding factor	(135.32 + 58.96) * 1.041 = 202.25 MJ/d

and lactation (M_{mp})		
Safety Margin above the animal requirement level	5% of (M_{mp})	0.05 * 202.25 = 10.11 MJ/d
ME allowance	M_{mp} *1.05	202.25 *1.05 = 212.36MJ/d

L = level of feeding as a multiple of MJ of ME for maintenance

Factorial procedure for calculating protein requirements

- Protein requirements for milk production is expressed in terms of both rumen degradable protein (RDP) and rumen un degradable protein (RUP). RDP is usually expressed in terms of microbial protein requirements

Microbial protein requirements

- Requirement for RDP in lactating cows depends upon the size of the animal (W kg), yield of milk (kg) and live-weight change (kg)
- These same factors that influence RDP and therefore microbial protein demand by the animal also determine the energy requirement
- Therefore, RDP requirement for lactating cows can be calculated from metabolisable energy intake (MEI) as:
    1. 8.34 * MEI g/day for mixed diets
    2. 8.67 * MEI g/day for silage based diets
    3. 7.84 * MEI g/day for diets consisting solely of grass silage

Tissue protein demand

- In addition to demand for protein by the microbial components, there is also demand for protein at tissue level which is constituted by the following:
    1. Maintenance requirement for protein g/kg is calculated as Protein g/kg = 2.19 g / kg $W^{0.75}$
    2. Milk protein component calculated as milk protein CP g/kg * 0.95. If milk protein values are not available then the protein requirement for milk production can be calculated from fat values as protein g/kg = 21.7 + 0.31F where F is milk fat content in g/kg. The 0.95 factor is used because the NPN fraction of milk is considered to be 5% and is regarded as excretory material which has already been used by the body and has therefore formed part of previously satisfied microbial protein demand.

6. The difference between the tissue protein demand (TP) and the microbial protein supply (MP) has to be made good by dietary protein which escapes break down in the rumen (RUP). Using the factor of the biological value and true digestibility, the requirement for rumen undegradable protein (RUP) of the diet can be calculated as

$$\text{RUP g/day} = \frac{\text{TP} - \text{RDP} * 0.8 * 0.8 * 0.85}{0.8 * 0.85}$$

RUP =1.47TP – 6.67ME

Example

Use the factorial method to Calculate the protein requirement of the 600 kg cow in the earlier example that produces 30 kg of milk containing 32 g CP/kg and losing 0.4 kg W/d .

Requirements	Formula	Formula value
Combined ME requirement MJ/day	$(M_p + M_m)$ * Level of feeding factor	(135.32 + 58.96) * 1.041 = 202.25 MJ/d
Requirement for RDP (g/d)	8.34 * MEI	8.34 * 202.25 = 1686.77 g/d
Protein for maintenance (g/d)	2.19 g/kg $W^{0.75}$	2.19 * $600^{0.75}$ = 265.5 g/d
Dermal loss (g/d)	0.1125 g/kg $W^{0.75}$	0.1125 *$600^{0.75}$=13.6 g/d
Milk production (g/d)	CP g/kg * 0.95	32 * 0.95 * 30 = 912.0 g/d
Tissue loss (g/d)	Wt loss * 112	-0.4 * 112 = -44.8 g/d
Total protein (TP) required or Total tissue protein required g/d for milk production	(Protein for maintenance + Dermal loss + Milk production – reduction in tissue protein demand due to weight loss)	265.5+13.6 + 912.0 - 44.8 = 1146.3
RUP requirement (g/d)	1.47TP – 6.67ME	1.47 * 1146.3 – 6.67 *

		202.25 = 336.1
RDP correction factor (g/d)	5%	0.05 * 1686.77 = 84.34
RDP Allowance	RDP requirement * 1.05	1686.77 * 1.05 = 1771.12
RUP allowance	UDP requirement * 1.05	336.1 * 1.05 = 352.91

Minimum requirement for CP is then (RDP allowance * 0.985) + (RUP allowance * 1.0625) = 1745 + 374 = 2119 g CP/d

If the blend of RDP and RUP is not ideal, the requirement may be considerably increased.

Protein requirement of an animal can also be estimated from a nitrogen balance trial.

If animals are fed on a number of rations which supply equal amounts DM and energy but

As nitrogen intake increases, there is a gradual reduction in the negative N balance until a point of equilibrium is reached where N intake is equivalent to zero balance where N is nether gained nor lost (maintenance point).

The level of N supplementation where there is neither gain nor loss of N sometimes ferred to as the zero N balance indicates the maintenance requirement level

- Above this point, any additional N supplementation results in positive nitrogen balance where the amount of N excreted is far less than the amount taken in suggesting that the body is using it for accretion as muscles.
- A stage is eventually reached when an increase in N intake fails to promote further N retention and the curve becomes horizontal.
- The point where further intake fails to promote further N retention is considered to be the combined maintenance and production N nutrient requirement for the class of animal (i.e., meant for beef production)
- If that amount is increased by 5% , then the allowance is obtained.