Equation changes since NorFor 2011 (EAAP No.130)

2014-12-23, 2016-09-15, 2016-10-15; 2017-03-09; 2017-12-28 ($iNDF_{504}$); 2019-09-16; 2019-09-17; 2020-01-27; 2020-05; 2020-10-11; 2021-10-12; 2022-01-21; 2022-05-25; 2022-11-25; 2022-12-09; 2023-05-03

Content

Chapter 3 Animal input and characteristics

Table 3.1 New input data for cows in NorFor

Input data	unit
Body condition score at calving, BCS_calv	BCS
Body condition score at drying off, BCS_end	BCS

Table 3.5. Default values for BW_birth, BW_mat for heifers, bulls and steers (kg), and kg_BCS for cows

Breed	BW_birth heifer	BW_birth bull	BW_mat heifer	BW_mat bulls	BW_mat steers	kg_BCS for cows
Early maturing dairy breeds						
Danish HO	40	41	640	950	750	60
Danish Red	40	41	660	950	750	60
Icelandic breed	33	33	470	800	700	45
Jersey	28	30	440	650	550	30
Norwegian Red	39	41	600	950	750	60
Swedish HO	39	41	640	950	750	60
Swedish Red	39	41	620	950	750	60
Crossbred of two large dairy breeds	39	40	630	950	750	60
Crossbred of Jersey and a large dairy reed	34	35	540	800	650	45
Early maturing beef breeds						
AA	36	38	650	950	750	60
BSH, Beef short horn	38	40	650	1100	900	60
BSW, Brown Swiss	38	40	650	1000	800	60
DEX	21	24	300	450	400	30
GAL	34	35	500	850	750	50
GVH, Gelbvieh	38	40	700	1100	900	60
HRF	40	42	700	950	750	60
HIG	29	30	500	700	600	50
PIN, Pinzgauer	38	41	750	1150	900	60
TIR	39	42	650	950	750	60
Late maturing beef breeds						
BB	44	47	750	1200	1050	70
BLO	44	47	800	1200	1050	70
CHA	46	49	800	1200	1050	70
CHI	50	55	850	1200	1050	70
LIM	41	43	700	1200	1050	60
PIE	41	43	600	1200	1050	60
SAL	39	41	750	1200	1050	70
SIM	44	46	750	1200	1050	70
WAG, Wagyu	34	36	700	1100	900	60
Early x Late maturing breeds						
Crossbred	42	44	750	1050	950	60

Chapter 4 Feed fraction characteristics

Eq 4.5 kdRestCHO=60

Where kdRestCHO is the degradation rate of the rest carbohydrate fraction (eq 4.1) (%/h). the degradation rate is generally set to 60%/h, with exception for some feedstuffs, e.g., dried beet pulp (both molassed and unmolassed), molasses, propylene glycol, propionic acid, glycerol where the rate is set to 150%/h.

NEW eq.4.8

$$IV = (\mathrm{C18\_1} \cdot 89.8 + \mathrm{C18\_2} \cdot 2 \cdot 89.8 + \mathrm{C18\_3} \cdot 3 \cdot 89.8 + \mathrm{C20\_5} \cdot 5 \cdot 81.7 + \mathrm{C22\_6} \cdot 6 \cdot 75)/100$$

Where IV is the iodine value of the feed stuffs fatty acids (g/100g FA), C18_1, C18_2, C18_3, C20_5 and C22_6 are the concentrations of the fatty acid oleic acid, linoleic acid, linolenic acid EPA and DHA (g/100g FA).

Chapter 5 Feed Analyses and Digestion Methods

5.1.1 Dry Matter in roughage

Eq. 5.7 this value on DM should the laboratory send to the NorFor Feed Analysis System (FAS)

5.2.2 Rumen degradation of starch

Eq. 5.25

$$kdST = (\mathrm{r\_kpc} \times rSTD)/(1000 - rSTD)$$

Where kdST is the degradation rate for starch (%/h), r_kpc is the ruminal passage rate for starch described in equation 13.4 and 13.5 (for DMI_{std} of 20 kg, 6,087 and 4,479 %/h respectively) and rSTD is the ruminal digestibility (g/kg starch). But if starch content is less than 60 g per kg DM and there is no scientifically rSTD then set kdST to 25% per hour

It is stated that soluble starch is zero and all starch is potentially degradable

Eq.5.26 pdST=1000, sST=0

5.2.3 Indigestible NDF

Eq 5.27 a

For individual concentrate feedstuffs the iNDF is still measured as the NDF residue in an *in situ* nylon bag after 288 h (as described in NorFor, 2011).

$$iNDF = NDF\_288/\mathrm{NDF} \times 1000$$

Eq 5.27b

If the roughage sample includes more than 50% legume plants, then the iNDF is calculated as

$$iNDF = (940 - 10.6 \times \mathrm{OMD} - 0.517 \times \mathrm{Ash})/\mathrm{NDF} \times 1000$$

Eq 5.27c

If the roughage sample includes less than 50% legume plants, then the iNDF is calculated as

$$iNDF = (506 - 5.60 \times \mathrm{OMD} - 0.159 \times \mathrm{Ash})/\mathrm{NDF} \times 1000$$

Where OMD is the organic matter digestibility in vivo (%) described in eq 5.12 to 5.18. Ash is the ash content (g/kg DM) and NDF is the NDF content (g/kg DM)

There is an exception when the calculation leads to less than 20 g iNDF per kg DM, then the feedstuff gets the value:

Eq 5.27d

$$iNDF = 1000 \times 20/\mathrm{NDF}$$

$$iNDF_{288} = 1000 - \left((1000 - \mathrm{iNDF}_{504}) \times 0.997 - 15.5\right)$$

according to Krämer et al (2012)

5.2.4 Indigestible starch

Eq. 5.29 iST=1000-STD

Where iST is the indigestible starch (g/kg ST), STD is the total tract starch digestibility (g/kg ST)

References

Krämer et al, 2012. Animal Feed Science Technology 177:40-51

Chapter 6 Feed calculations in NorFor

In the calculation of kdNDF

Eq. 6.3

Where …; OMD is organic matter digestibility expressed as g/g; …

Eq 6.7

$$pdNDFcorr = 1000 - iNDF$$

Where iNDF is the indigestible NDF (g/kg NDF) described in eq 5.27 b, c and d

Eq 6.10

$$FV = \frac{0.86 - OMD \cdot 0.005}{0.94 + 0.56 \cdot exp^{-0.000029 \cdot \left(\frac{NDF}{10}\right)^{2.9}}} \cdot corr$$

(Clarifying Euler's constant e to exp)

Where …; corr is a correction factor explained in eq 6.11.

Eq 6.11

$$corr = \left(1 - \left(\frac{-0.000531 \cdot \left((TAF)^2 - 6400\right)}{100} + \frac{-4.765 \cdot (ln(NH_3N) - ln(50))}{100}\right)\right)$$

Where corr is a correction factor when fill value (equation 6.10) is corrected for silage fermentation products. TAF is the content of total fermentation acids in the ensiled feed, g/kg DM, Equation 4.6 ; and NH_3N of ammonia N in the ensiled feeds, g/kg N. When TAF is lower than 80 g/kg DM the value 80 should be used. When NH_3N is lower than 50 g/kg N the value 50 should be used. The factor corr is equal to 1 when both TAF is less than 80 g/kg DM and NH_3N is less than 50 g/kg N.

Chapter 7 Digestion and metabolism in the gastroinestinal tract

7.1.1 Rumen fractional passage rates

Eq 7.1 the equation changed for Jersey cows to 0.8 * r_kpl

Eq 7.2 the equation changed for Jersey cows to 0.8 * r_kpr

Eq 7.3 the equation changed for Jersey cows to 0.8 * r_kpc

Eq 7.4 the equation changed for Jersey cows to 0.8 * r_kpNDFc

A linear passage rate for roughage NDF was developed by Åkerlind *and* Nielsen (2019) based on 290 feeding trials.

Eq. 7.5 $r\_kpNDFr = 0.7792 + 0.09296 * NDF\_BW$

the equation changed for Jersey cows to 0.8 * r_kpNDFr

Where r_kpNDFr is the fractional passage rate of pdNDF in roghage particles, %/h : NDF_BW is the NDF intake per kg current body weight, g/kg.

7.1.6 Microbial efficiency and chemical composition

Eq 7.28 r_emCP

Where BW for Jersey cows is 440 kg

Eq. 7.33b $r\_mRestCHO = r\_mCP \cdot 270\ /512$

Where r_mCP and r_mRestCHO are the microbial crude protein and microbial rest fraction in the rumen where CP and RestCHO represent 512 and 270 gram per kg microbial organic matter respectively

7.2 Small intestine

Eq 7.40.

$$sid\_ST = \left(\sum_i (DMI_i \cdot ST_i) - rd\_ST - \sum_i \left(DMI_i \cdot ST_i \cdot \frac{iST_i}{1000}\right)\right) \cdot \left(0.0052 \cdot \frac{100 \cdot rd\_ST}{\sum_i (DMI_i \cdot ST_i)} + 0.2864\right)$$

Where DMI_i is the dry matter intake of the i'th=1… feedstuff (kg /day), ST_i is the starch content (g/kg DM), rd_ST is the rumen degraded starch (g/day) described in eq. 7.14 an iST_i is the indigestible fraction of starch (g/kg ST).

7.3 Large intestine

Eq 7.49

$$lid\_ST = \left(\sum_i (DMI_i \cdot ST_i) - rd\_ST - \sum_i \left(DMI_i \cdot ST_i \cdot \frac{iST_i}{1000}\right)\right) \cdot \left(-0.0052 \cdot \frac{100 \cdot rd\_ST}{\sum_i (DMI_i \cdot ST_i)} + 0.7136\right)$$

Where DMI_i is the dry matter intake of the i'th=1… feedstuff, kg/day; ST_i is the starch content, g/kg DM; rd_ST is the rumen degraded starch, g/day, described in eq 7.14 and iST_i is the indigestible fraction of starch, g/kg ST.

A fixed value of 100 g/kg degraded carbohydrates is used for the efficiency of microbial protein synthesis in the large intestine (Dierick *et al.*, 1990)

Eq 7.50 $li\_mCP = (lid_{NDF} + lid_{ST} + r\_mST \cdot 0.1 + \mathrm{r}\_mRestCHO \cdot 0.75) \cdot 0.10$

Where li_mCP is the microbial protein synthesis in the large intestine, g/d; lid_NDF is the degraded NDF in the large intestine, g/d, eq 7.48; lid_ST is the degradation of starch in the large intestine, g/d, eq7.49, r_mST is the microbial synthesised starch in the rumen, g/d, eq 7.33; the factor 0.1 is related to 10% of the rumen synthesised starch is degraded in the large intestine eq7.33; r_mRestCHO is the microbial synthesised rest fraction i.e. cell walls, g/d, eq7.33b; the factor 0.75 is related to the proportion of the cell walls is digested in the large intestine; the factor 0.10 is the efficiency of microbial protein synthesis in the large intestine

Eq 7.51a $li\_mOM = li\_mCP \cdot 1000/512$

Eq 7.51b $li\_mCFat = li\_mCP \cdot 167/512$

Eq 7.51c $li\_mST = li\_mCP \cdot 51/512$

Eq 7.51d $li\_mRestCHO = li\_mCP \cdot 270/512$

Where li_mOM, li_mCP, li_mCFat, li_mST, li_mRestCHO are the microbial organic matter, microbial crude protein, microbial crude fat, microbial starch and microbial rest fraction in the large intestine where CP, CFat, ST and RestCHO represent 512, 167, 51 and 270 gram per kg OM respectively

Eq. 7.52 $td\_CP = \sum_i (DMI_i \cdot CP_i) - (\sum_i (DMI_i \cdot CP_i) - rd\_CP - sid\_CP + r\_mCP + r\_outOM \cdot 0.03 \cdot 3 \cdot 0.4 + si\_outOM \cdot 0.009 + li\_mCP)$

Where td_CP is the apparent total tract digestion of crude protein, g/d; DMI_i is the dry matter intake of the i=1…n'th feedstuff, kg/d; CP_i is the crude protein content in the i=1…n'th feedstuff, g/kg DM; rd_CP is the rumen degraded crude protein, g/d, eq 7.8; sid_CP is the small intestine digested crude protein, g/d, eq 7.37; r_mCP is the rumen microbial synthesised crude protein eq 7.30; r_outOM is the flow of organic matter from rumen into the small intestine, g,/d, eq 7.36; si_outOM is the flow of organic matter from the small intestine into the large intestine, g/d, eq 7.47; the factors 0.03, 3 and 0.4 is the are explained in eq 7.47

In equation 7-52, 9 g protein per kg OM flowing into the large intestine is used as an estimate of endogenous protein excretion in the large intestine (Marini et al., 2008)

Eq. 7.54 $td\_CPcorr = \sum_i(DMI_i \cdot CPcorr_i) - (\sum_i(DMI_i \cdot CP_i) - rd\_CP - sid\_CP + r\_mCP + r\_outOM \cdot 0.03 \cdot 3 \cdot 0.4 + si\_outOM \cdot 0.009 + li\_mCP)$

Equation 7.54 is similar to equation 7.52 except that ammonia- and urea-corrected CP ($CPcorr_i$, eq 4.4) is used for input.

References

Dierick, N.A., I.J. Vervaeke, J.A. Decuypere & H.K. Henderickx, 1990. Bacterial protein synthesis in relation to organic matter digestion in the hindgut of growing pigs; contribution of hindgut fermentation to total energy supply and growth performance. Journal of Animal Physiology and Animal Nutrition 63:220-235.

Marini, J.C., D.G. Fox & M.R. Murphy, 2008. Nitrogen transactions along the gastrointestinal tract of cattle: A meta-analytical approach. Journal of Animal Science 86:660-679.

Åkerlind, M. & N.I. Nielsen, 2019. Evaluation of NorFor's prediction of neutral detergent fibre digestibility in dairy cows. Proceedings of the 10th Nordic Feed Science Conference June 11-12, 2019, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Chapter 9 Animal requirements and recommendations

9.1 Energy

9.1.4 Growth

Eq 9.4 is valid for both 1st and 2nd calvers

Eq 9.9

$$gain\_fat = \left(\left(\frac{1000 \cdot Fat\_mass}{EBW}\right) \cdot \left(\frac{(factor\_2 + 2 \cdot factor\_3 \cdot ln(EBW)) \cdot factor\_4}{Factor\_4^{1,78}}\right)\right) \cdot \left(\frac{EBWG}{1000}\right)^{1.78}$$

Where… EBWG is the daily empty body weight gain, g/day…

9.1.5 Mobilisation and deposition for lactating cows

Eq 9.17

$$NEL\_dep = BW\_change\_mobdep \cdot 31.0$$

If change_BCS >0, then $NEL\_dep = change\_BCS \cdot kg\_BCS \cdot 31.0$

Where BW_change_mobdep is the body weight change during mid and late lactation depending on deposition (kg/day)

Eq 9.18

$$NEL\_mob = -1 \cdot BW\_change\_mobdep \cdot 24.8$$

If change_BCS <0, then $NEL\_mob = change\_BCS \cdot kg\_BCS \cdot 24.8$

Where BW_change_mobdep is the body weight change during early lactation depending on mobilisation (kg/day) described in NEW eq 9.19**d**

Eq 9.19 and figure 9.3 in the book should be excluded

Table 9.6, Eq 9.19 (about NEL_variable) and figure 9.3 are deleted

NEW eq 9.19 a

$$BW\_mob = a \cdot \left(1 + 2 \cdot \frac{BCS\_calv - 3.5}{3.5}\right)$$

New eq 9.19 b

$$b = 0.04{+}0.05 \cdot BW\_m\text{ob-}0.305 \cdot (\text{BCS\_calv-BCS\_end}) \cdot 2$$

NEW eq 9.19 c

$$c = \frac{b}{2.4207 / -7.3955} + 0.151 \cdot \left(-\left(BCS\_calv - BCS\_end\right) \cdot 2 \cdot 2.55\right)$$

NEW eq 9.19 d

$$BW\_change\_mobdep = \begin{pmatrix} \text{BW\_mob} + \\ b \cdot \sqrt{\text{DIM}} \cdot \text{LN}(\text{DIM}) \\ + c \cdot (\text{LN}(\text{DIM}))^2 \end{pmatrix} - \begin{pmatrix} \text{BW\_mob} + \\ b \cdot \sqrt{(\text{DIM - 1})} \cdot \text{LN}(\text{DIM - 1}) \\ + \text{c} \cdot (\text{LN}(\text{DIM - 1}))^2 \end{pmatrix}$$

If DIM=1

$$BW\_change\_mobdep = \begin{pmatrix} \text{BW\_mob} + \\ b \cdot \sqrt{\text{DIM} + 2.1} \cdot \text{LN}(\text{DIM} + 2.1) \\ + c \cdot (\text{LN}(\text{DIM} + 2.1))^2 \end{pmatrix} - \begin{pmatrix} \text{BW\_mob} + \\ b \cdot \sqrt{(\text{DIM} + 2 \text{ - } 1)} \cdot \text{LN}(\text{DIM} + 2 \text{ - } 1) \\ + \text{c} \cdot (\text{LN}(\text{DIM} + 2 \text{ - } 1))^2 \end{pmatrix}$$

NEW Eq 9.19d $BW\_dep = a \cdot \left(1 + 2 \cdot \frac{BCS\_end - 3.5}{3.5}\right)$

Where BW mob is the total body weight loss due to mobilisation in early lactation (kg), a is a factor taken from NEW table 9.6, BCS_calv is the body condition score at calving; BCS_end is the body condition score at drying off, BW_change_mobdep is the daily body weight change (kg/day), DIM is days in milk, BW_dep is the total body weight recovery due to deposition in mid and late lactation.

NEW Table 9.6. Factor **a** shows the mobilisation (kg) in BW change in early lactation (DIM 0 to approx. 70) provided BCS_calv is 3.5. Factor **a** also shows the deposition in mid and late lactation (DIM approx. 70 to 300) provided that BCS_end is 3.5

Breed	Lactation 1	Older
SLB; SDM; other	27	36
RDM, SRB, NRF	20	30
ISL	15	20
JER	20	27
AA, BB, BLO, BSH, BSW, CHA, CHI, DEX, GAL, GVH, HIG, HRF, LIM; PIE, PIN, SAL, SIM, TIR, WAG	a=kg_BCS*0.5*0.6*0.6	a=kg_BCS*0.5*0.6*0.6

If nothing else is stated assume that body condition score at calving (BCS_calv) is 3.5, body condition score at end of lactation (BCS_end) is 3.5 and the mobilisation in early lactation is approximately 0.5 BCS unit until lactation day 70. The equation is valid between DIM 1 to 300.

9.2 Protein

9.2.1 Maintenance

Eq 9.22 $AAT_N\_ma\text{int} = EUN + Scurf + MFP$

Where AAT_N_maint is the daily AAT_N requirement for maintenance, g/d; EUN is the endogenous urinary nitrogen, equation 9.22b; Scurf is skin cells and hair, equation 9.22c; MFP is metabolic fecal protein, equation 9.22d.

Eq 9.22b $EUN = \frac{2.75 \cdot BW\_cur^{0.5}}{0.67}$

Eq 9.22c $Scurf = \frac{0.2 \cdot BW\_cur^{0.6}}{0.67}$

Eq 9.22d $MFP = \frac{r\_outOM \cdot 0.03 \cdot 0.5 \cdot 3 \cdot 0.4}{0.67} + si\_outOM \cdot 0.025 \cdot 0.5$

Where BW_cur is current body weight, kg; r_out_OM is the amount of OM leaving the rumen and entering the small intestine, equation 7.36; si_outOM is the amount of OM leaving the small intestine and entering the large intestine equation 7.47; 0.67 is a fixed utilization coefficient of AATN for maintenance; 0.03 refers to the amount of endogenous CP, which is 3% of the OM entering the small intestine from the rumen; 3 is a multiplier to include all endogenous CP produced in the small intestine; 0.5 is the AA-N proportion of endogenous CP; 0.4 is used because of 60% of endogenous CP is reabsorbed; and 0.025 refers to the amount of endogenous CP, which is 2,5% of OM entering the large intestine from the small intestine.

Eq 9.26 $Avail\_AAT_N = AAT_N - AAT_N\_maint - AAT_N\_gain - AAT_N\_gest) + AAT_N\_mob - AAT_N\_dep$

Eq 9.29 equation should be exchanged is equal to 15.1

9.2.2 Lactation

Eq 9.30 AAT-balance is only valid for dry cows not lactating cows. Minimum level AAT-balance is 100 for dry cows and the max level is deleted.

Figure 9.6 should be excluded

9.2.3 Growth

Eq 9.32. AAT_gain is valid for both 1st and 2nd calvers

Eq 9.35 if energy requirement of growth is less than 0.15 MJ per day then AAT_NEG =0 (the purpose is for breeding bulls)

Eq 9.38 $AAT\_NEG\_Min = \frac{(1.88 - 0.00176 \cdot BW\_cur - 0.2283 \cdot ADG/1000 + 0.0000019014 \cdot BW\_cur^{1.83})}{0.03821 \cdot 2 - 0.000000016 \cdot 5 \cdot 14^{4}} - 1$

if the animal's growth is less than 11 grams per day then AAT_NEG_Min=0 (the purpose is for breeding bulls)

9.3 PBV

Eq 9.43 $PBV\_DM\_Min = 10$ for cows

Figure 9.11 deleted

9.8 Minerals

Mineral requirements are generally based on a factorial approach in which the requirements for maintenance, milk production, growth and gestation are considered. The requirements also include a safety margin, although this margin is not quantified, but based on the lowest absorption coefficients from the literature. Furthermore, these low absorption coefficients also apply for mineral supplements, although they have higher true absorption coefficients (NASEM, 2016; NASEM, 2021).

9.8.1 Macro minerals

Recommendations for calcium, phosphorus, magnesium, potassium, sodium and chlorine for cows and growing cattle of dairy and beef breeds are calculated using the following equations. Note that the absorption coefficients range from 16% for magnesium to 100% for sodium and potassium:

$Ca\_int\ a\ ke\_Min = (Ca\_ma\ int\ + Ca\_milk + Ca\_gain + Ca\_gest) \ / \ Ca\_abscoeff$		Eq 9.44a
Ca_abscoeff=0.45		Eq 9.44b
$Ca\_maint = \ 0.9 \times DMI\_predict$	for dairy breeds	Eq 9.45a
$Ca\_ma\ int\ = \ (0.0154 \cdot BW)$	for other breeds	Eq 9.45b
$Ca\_milk = (0.295 + 0.239 \times p\_milk/10) \times MY$	for dairy breeds	Eq 9.46a
$Ca\_milk = 1.23 \times MY$	for other breeds	Eq 9.46b
$Ca\_gain = 9.83 \cdot (BW\_mat)\hat{}0.22 \cdot (BW)\hat{}(-0.22) \cdot ADG/1000$	for dairy breeds	Eq 9.47a
$Ca\_gain = 7.1/100 \times gain\_prot$	for other breeds	Eq 9.47b
$Ca\_gest = (0.02456 \cdot e\hat{}((0.05581 - 0.00007 \cdot gest\_day\ ) \cdot gest\_day\ ) - 0.02456 \cdot e\hat{}((0.05581 - 0.00007 \cdot (gest\_day - 1) \cdot (gest\_day - 1))\ )\ ) \times BW/715$		Eq 9.48

$P\_int\ a\ ke\_Min = (P\_ma\ int\ + P\_milk + P\_gain + P\_gest) \ / \ P\_abscoeff$		Eq 9.49a
$P\_abscoeff = 0.72$	for dairy breeds	Eq 9.49b
$P\_abscoeff = 0.68$	for other breeds	Eq 9.49c
$P\_maint\ = 0.0006 \times BW\_cur\ + \ factor1 \times DMI\_predict$	for dairy breeds	Eq 9.50a
$P\_ma\ \mathrm{int}\ = \ 0.016 \cdot BW$	for dairy breeds	Eq 9.50b
$P\_milk = (\ 0.48\ + \ 0.13\ \times\ p\_milk/10\ ) \times\ milk$	for dairy breeds	Eq 9.51a
$P\_milk = 0.95 \times milk$	for other breeds	Eq 9.51b
$P\_gain = 1.2\ + \ 4.635\ \cdot \mathrm{BW\_mat}\ \hat{}0.22 \cdot BW\ \hat{}\ - 0.22\ \cdot ADG/1000) \cdot$	for dairy breeds	Eq 9.52a
$P\_gain = 3.9 \times gain\_prot/100$	for other breeds	Eq 9.52b
$P\_gest = (0.02743\ \cdot e\ \hat{}((0.05527 - 0.000075\ \cdot gest\_day\ ) \cdot gest\_day)\ - \ 0.02743\ \cdot e\ \hat{}((0.05527 - 0.000075 \cdot (gest\_day - 1\ ) \cdot (gest\_day - 1))\ )$		Eq 9.53

$Mg\_intake\_Min = (Mg\_maint + Mg\_milk + Mg\_gain + Mg\_gest) \; / \; Mg\_abscoeff$ Eq 9.54a

$Mg\_abscoeff = 0.232$ for lactating cows of dairy breeds Eq 9.54b

Corresponds to $Mg\_abscoeff = (34.9 - 0.450 \times K\_DM)/100$ where K_DM is dietary potassium of 26 g/kg DM (formula after CVB, 2005) and absorption of MgO (according to NASEM, 2021)

$Mg\_abscoeff = 0.214$ for dry cows and growing cattle of dairy breeds Eq 9.54c

Corresponds to $Mg\_abscoeff = (34.9 - 0.450 \times K\_DM)/100$ where K_DM is dietary potassium of 30 g/kg DM (formula after CVB, 2005)

$Mg\_abscoeff = 0.16$	for other breeds	Eq 9.54d
$Mg\_maint = 0.0007 \cdot BW + 0.3 \cdot DMI\_predict$	for dairy breeds	Eq 9.55a
$Mg\_maint = 0.003 * BW$	for other breeds	Eq 9.55b
$Mg\_milk = 0.11 \times MY$	for dairy breedsfor	Eq 9.56a
$Mg\_milk = 0.12 \times MY$	for other breeds	Eq 9.56b
$Mg\_gain = 0.45 \times gain$		Eq 9.57
$Mg\_gest = 0.30 \times BW \; / \; 715$	for dairy breeds	Eq 9.58a
$Mg\_gest = 0.12$	for other breeds gest_day 1-80	Eq 9.58b
$Mg\_gest = 0.21$	for other breeds gest_day 81-190	Eq 9.58b
$Mg\_gest = 0.33$	for other breeds gest_day 191-285	Eq 9.58b

$Na\_intake\_Min = ((Na\_maint + Na\_milk + Na\_gain + Na\_gest)) \; / \; (Na\_abscoeff)$		Eq 9.59a
$Na\_abscoeff = 1.0$		Eq 9.59b
$Na\_maint = 1.45 \times DMI\_predict$	for dairy breeds	Eq 9.60a
$Na\_maint = (0.015 \times BW)$	for other breeds	Eq 9.60b
$Na\_milk = (0.40 \times MY)$		Eq 9.61
$Na\_gain = 1.4 \times ADG/1000$		Eq 9.62
$Na\_gest = 1.4 \times BW/715$		Eq 9.63

$K\_intake\_Min = (K\_maint + K\_milk + K\_gain + K\_gest)/K\_abscoeff$	for dairy breeds	Eq 9.64a
$K\_abscoeff = 1$	for dairy breeds	Eq 9.64b
$K\_intake\_Min = 7 * DMI\_predict + K\_milk$	for lactating cows of other breeds	Eq 9.65c
$K\_intake\_Min = 6 * DMI\_predict$	for dry cows and growing cattle of other breeds	Eq 9.65d
$K\_maint = factor2 \times BW + 2.5 \times DMI\_predict$	for dairy breeds	Eq 9.65
$K\_milk = 1.5 \cdot MY$	for dairy breeds	Eq 9.66
$K\_gain = 2.5 \cdot \frac{ADG}{1000}$	for dairy breeds	Eq 9.67
$K\_gest = (1.03 \cdot (BW)/715)$	for dairy breeds	Eq 9.68

$Cl\_intake\_Min = ((Cl\_maint + Cl\_milk + Cl\_gain + Cl\_gest)) \; / \; (Cl\_abscoeff)$	Eq 9.69a
$Cl\_abscoeff = 0.92$	Eq 9.69b
$Cl\_maint = 1.11 * DMI\_predict$	Eq 9.70
$Cl\_milk = 1.0 * MY$	Eq 9.71
$Cl\_gain = 1.0 * ADG/1000$	Eq 9.72
$Cl\_gest = 1.0 * BW/715$	Eq 9.73

Where: X_intake_Min is the daily recommendation of micromineral X, g/day; X_maint, X_milk, X_gain, X_gest are the animal's requirement of X for maintenance, milk production, weight gain and gestation respectively, g/day; X_abscoeff is the absorbtion coefficient of X, g/g; DMI_predict is the predicted DM intake kg/d, Eq 9.74, 9.75, 9.76a or 9.76b; MY is the daily milk yield, kg/d, p_milk is the protein content in milk, g/kg, BW is the current body weight, kg; BW_mat is the mature body weight, kg, Table 3.5; ADG is the average daily gain, g/day; gain_prot is the daily protein retention, g/day, Eq 9.8; gest_day is the day of gestation, factor1 is 1.0 for cows and 0.8 for growing cattle; factor2 is

0.2 for lactating and 0.07for non-lactating and growing cattle. For dairy breeds equations are from NASEM (2021) and for other breeds NASEM (2016).

9.76a for lactating cows

$$DMI\_predict = ((3.7 + \text{Parity} \cdot 5.7) + 0.305 \cdot \text{ECM} \cdot 3.14/4.184 \ + 0.022 \cdot \text{BW} + (-0.689 + \text{Parity} \cdot -1.87) \cdot \text{BCS}) \cdot (1 - (0.212 + \text{Parity} \cdot 0.136) \cdot (\text{Exp}\hat{\ }((-0.053 \cdot \text{DIM}))))$$

Where DMI_predict is the predicted feed intake, kg DM/day (NASEM, 2021); BW the current body weight, kg; Parity is the share of multiparous cows, 0 for primiparous and 1 for older cows; BCS is 3.5; ECM is the energy corrected milk kg/day, Eq 3.1 and 3.2; 3.14is the energy content MJ/kg ECM; 4.184 is ratio of calory/Joule.

9.76b for dry cows

$$DMI\_predict = BW * 10/500$$

Where DMI_predict is the predicted feed intake, kg DM/day (Jardstedt, 2019); BW the current body weight, kg; 10 is the NDF intake g/kg BW; 500 is a recommended NDF content in the diet, g/kg DM.

9.8.2 Micro minerals

Recommendation for the micro minerals iron, manganese, zinc, copper cobalt, selenium and iodine are shown in Table 9.15. Recommendations for iron, manganese, zinc and copper for cows and growing cattle of dairy breeds are calculated factorially (Eq 9.77 to 9.80)

Table 9.15. Recommendation of micro minerals for cows and growing cattle of dairy breeds (SRB, SLB, JER. DH, RDM, NRF, ISL, CRSJ, CRSD) and other breeds. For dairy breeds equations are from NASEM (2021) and for other breeds NASEM (2016)

	Iron	Manganese	Zinc	Copper	Cobalt	Selenium	Iodine
Cows of dairy breeds	Eq 9.77	Eq 9.78	Eq 9.79	Eq 9.80	0.2	0.2	1.0
Growing cattle of dairy breeds	Eq 9.77	Eq 9.78	Eq 9.79	Eq 9.80	0.15	0.1	0.5
Cows of other breeds	50	40	30	10	0.2	0.2	1.0
Growing cattle of other breeds	50	20*	30	10	0.15	0.1	0.5

* For heifers of other breeds require 40 mg/kg DM.

$Fe\_intake\_Min = (Fe\_maint + Fe\_milk + Fe\_gain + Fe\_gest) \ / \ Fe\_abscoeff$ Eq 9.77a
$Fe\_abscoeff = 0.10$ Eq 9.77b
$Fe\_maint = 0$ Eq 9.77c
$Fe\_milk = 1.0 \cdot MY$ Eq 9.77d
$Fe\_gain = 34 \cdot ADG/1000$ Eq 9.77e
$Fe\_gest = 0.025 \cdot BW \cdot BW/715$ Eq 9.77f

$Mn\_intake\_Min = (Mn\_maint + Mn\_milk + Mn\_gain + Mn\_gest)/Mn\_abscoeff$ Eq 9.78a
$Mn\_abscoeff = factorMn$ Eq 9.78b
$Mn\_maint = 0.0026 * BW$ Eq 9.78c
$Mn\_milk = 0.03 * MY$ Eq 9.78d
$Mn\_gain = 0.7 * ADG/1000$ Eq 9.78e
$Mn\_gest = 0.00042 * BW * BW/715$ Eq 9.78f

$Zn\_\text{intake}\_Min = (Zn\_maint + Zn\_milk + Zn\_gain + Zn\_gest)/Zn\_abscoeff$ Eq 9.79a

$Zn\_abscoeff = 0.2$ Eq 9.79b

$Zn\_maint = 5 \times DMI\_predict$ Eq 9.79c

$Zn\_milk = 4 \times MY$ Eq 9.79d

$Zn\_gain = 24 \times ADG/1000$ Eq 9.79e

$Zn\_gest = 0.017 \times BW \times BW/715$ Eq 9.79f

$Cu\_intake\_Min = (Cu\_maint + Cu\_milk + Cu\_gain + Cu\_gest)/Cu\_abscoeff$ Eq 9.80a

$Cu\_abscoeff = 0.05$ Eq 9.80b

$Cu\_maint = 0.0145 \cdot BW$ Eq 9.80c

$Cu\_milk = 0.04 \cdot MY$ Eq 9.80d

$Cu\_gain = 2 \cdot ADG/1000$ Eq 9.80e

$Cu\_gest = 0.0023 \cdot BW$ Eq 9.80f

Where: x_intake_Min is the daily recommendation of micromineral x for cows, heifers, bulls or steers of the dairy breeds SRB, SLB, JER. DH, RDM, NRF, ISL, CRSJ, CRSD, g/day; x_maint, x_milk, x_gain, x_gest are the animal's requirement of x for maintenance, milk production, weight gain and gestation respectively, g/day; x_abscoeff is the absorbtion coefficient of x, g/g; DMI_predict is the predicted DM intake kg/d, Eq 9.74, 9.75, 9.76a or 9.76b MY is the daily milk yield, kg/d; BW is the current body weight, kg; ADG is the average daily gain, g/day; the requirement for gestation is valid when gestation day is between 190 to 285; FactorMn is 0.0042 for cows and 0.005 for growing cattle. For dairy breeds equations are from NASEM (2021).

9.9 Vitamins

Table 9.16. Recommendation of supplemented Vitamin A, D and E (IU/kg BW)

	Vitamin A	Vitamin D	Vitamin E
Lactating cows of dairy breeds	110*	40	0.8
Dry cows of dairy breeds	110	30	1.6**
Reproducing heifers of dairy breeds	110	30	0.8**
Growing cattle of dairy breeds	80	10	0.6
Lactating cows of other breeds	84	40	0.8
Dry cows of other breeds	60	30	1.6
Pregnant heifers of other breeds	60	30	0.8
Growing cattle of other breeds	47	5.7	0.6

* Lactating cows of dairy breed producing more than 35 kg milk require more Vitamin A (IU/kg BW) =110+1000x(MY-35)/BW; **Dry cows more than 260 days of gestation require more Vitamin E =3.0 IU/kg BW; ***Heifers more than 220 days of gestation require more vitamin E 1.6 IU/kg BW and more than 160 days of gestation 3.0 IU Vitamin E/kg BW.

Table 9.15b Maximal tolerable level (MTL) of macro minerals (g/kg DM) and micro minerals (mg/kg DM) (EU 2014, 2015, 2016, 2017a, 2017b, 2018, 2019; NRC 2005)

	Ca	P	Mg	K	Na	Cl	S	Fe	Mn	Zn	Cu	Co	Se	I	Mo
MTL	15	7	6	20	12	18	4	450 /0.88	120 /0.88	120 /0.88	30 /0.88	1 /0.88	0.5 /0.88	5 /0.88	5

9.7 Fatty acids

NEW Eq 9.81 $IV\_DM\_Max = 45$

Where IV_DM_Max is the highest recommendation of iodine value of the ration (g iodine per kg DM) (reference M.R. Weisbjerg)

9.10 Individual amino acids

NEW Eq 9.82 $His\_AAT\_Min = 2.2$

NEW Eq 9.83 $Lys\_AAT\_Min = 6.4$

NEW Eq 9.84 $Met\_AAT\_Min = 2.2$

NEW. Regarding breeding bulls, grown-up bulls or bulls that grow less than 11 grams per day, approximately have less energy requirement for growth than 0.15 MJ per day. For calculating rations to grown up bulls, use AAT-balance, not AAT/NEG.

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Chapter 10 Prediction of voluntary feed intake

Eq. 10.2

$$IC\_cow = a \cdot DIM^{b} \cdot exp^{c \cdot DIM} - DIM^{-d} + e \cdot \left(ECM + \frac{(-NEL\_mob + NEL\_dep) \cdot h}{3.14}\right) + (BW - f) \cdot g$$

where IC_cow is the intake capacity of a lactating cow (FV/day), the factors a, b, c, d, e, f, g and h is taken from Table 10.5, DIM is the days in milk, ECM is the production of energy corrected milk (kg/day) described in eq 3.2, NEL_mob is the energy supply from body reserve mobilization (MJ/day) described in eq 9.18, NEL_dep is the energy requirement for deposition (MJ/day) described in eq 9.17 and BW is the live body weight (kg)

Table 10.5

Cow category	a	b	c	d	e	f	g	h
1st calvers large breeds	3.07	0.134	-0.00045	0.003	0.091	500	0.006	0.7
older large breeds	3.30	0.134	-0.0004	0.003	0.091	575	0.006	0.5
1st calvers JER	2.50	0.134	-0.0005	0.06	0.098	360	0.006	0.4
Older JER	2.70	0.134	-0.0007	0.03	0.106	405	0.006	0.4
1st calvers ISL	2.51	0.134	-0.0012	0.025	0.091	370	0.006	0.5
Older ISL	2.77	0.134	-0.0011	0.003	0.091	450	0.006	0.5

Eq 10.7

$$FV\_SubR = 0.97 + 5.62 \cdot \left(\frac{ST\_SU\_DM}{1000} - 0.2119\right) \cdot 0.1 - 0.1932 \cdot \left(\frac{ST\_SU\_intake}{1000} - 5.122\right) \cdot 0.05$$

where FV_SubR is the roughage substitution correction factor, 0 to 1; ST_SU_DM is the proportion of starch and sugars in the diet, g/kg DM; ST_SU_intake is the starch and sugar intake, g/d; 0.1 and 0.05 are constants for facilitating the optimization when formulating rations.

Eq 10.8 $FV\_MR = 1.453 - \frac{2.530}{1+exp\left(^{(0.466-FV\_r)}/_{0.065}\right)}$

Eq 10.9, 10.10, 10.12, 10.13

$$IC\_animal = (factor\_1 \cdot BW\_cur + factor\_2 \cdot ADG\_LW) \cdot IC\_exercize \cdot IC\_gest$$

Where

Maturing	Gender	factor_1	factor_2
Early	Heifers, Steers	0.008787	0.00041996
Early	Bulls	0.006132	0.0006797
Late	Heifers, Steers	0.006940	0.0002699
Late	Bulls	0.004169	0.0009847

early maturing breeds: HO, JER, DR, NR, SR, ISL, AA, HRF, DEX, TIR, HIG, GAL, BSH, BSW, PIN

late maturing breeds: CHA, BLO, SIM, LIM, BB, PIE, CHI, WAG, SAL, Crossbreds

Eq 10.11 IC_gest=1 for steers and bulls

NEW equation IC_exercize 1.0 for tied up and 1.05 for loose housed animals or animals on pasture

Eq 10.15 where the FV_SubR is the roughage substitution correction factor, shown in figure 10.5; conc_share is the proportion of concentrate in the diet on a DM basis, %.

Eq 10.15 $FV\_MR = 0$

Chapter 12 Predictions

12.1 Prediction of milk yield

Eq 12.2

$$Protein\_respons = Avail\_AAT_N \cdot \left(189.4 - 11.14 \cdot \frac{Avail\_AAT_N}{ECM\_response \cdot 3.14} + 0.215 \cdot \left(\frac{Avail\_AAT_N}{ECM\_response \cdot 3.14}\right)^2\right) / 100$$

Where the expression ECM_response times 3.14 is equal to the net energy available for milk production

NEW eq 12.21

Enteric methane production of cows according to Nielsen *et al*. (2013)

$$CH4 = (1.23 \cdot DMI - 0.145 \cdot FA\_DM + 0.012 \cdot NDF\_DM) \times (1 + CH4_{reduction}/100)$$

Where CH4 is enteric methane production, MJ per day; DMI is the dry matter intake, kg/day; and FA_DM the fatty acid concentration in the ration, g/kg DM. CH4_reduction is the estimated reduction of the feed additives trinitrooxypropanol (triNOP) and nitrate, % equation

Enteric methane production of growing cattle

$$CH4 = (1.6105 + 0.5615 \cdot DMI\_c + 1.3511 \cdot DMI\_r + 0.000309 \cdot rd\_NDF - 0.00379 \cdot FA\_intake - 0.00266 \cdot Ash\_intake)$$

Where CH4 is enteric methane production, MJ per day; DMI_c is intake of concentrate, kg DM/day; DMI_r is intake of roughage, kg DM/day; rd_NDF is tha rumen degraded NDF, g/day, Equation 7.21; FA_intake is the intake of fatty acids, g/day; Ash_intake is the intake of ash, g/day.

NEW eq 12.22

$$Ym = \frac{CH4}{GE} \cdot 100$$

Where Ym is the efficiency, %, CH4 is the enteric methane production, MJ/day, Equation 12:21 and GE is the gross energy intake, MJ/day, Equation 8.1.

NEW eq 12.23

$$CH4\_g = \frac{CH4}{55.65} \cdot 1000$$

Where CH4_g is the enteric methane production in gram, g/day; CH4 is the enteric methane production, MJ/day, Equation 12.21; 55.65 is the energy concentration of methane, MJ/kg.

NEW eq 12.24

$$CO2e\_animal = \frac{CH4\_g \cdot 28}{1000}$$

Where CO2e_animal is the carbon dioxide equivalents of enteric methane, kg /day, CH4_g is the enteric methane production, g/day, Equation 12.23; the factor 28 is the conversion factor from methane to CO2e, g/g (IPCC).

Chapter 12.3.4 Excretion of faeces and its composition

Amount of faeces estimated as

NEW eq 12.25

$$kg\_faeces = (DM\_faeces)/1000/0.135$$

Where kg_faeces is the fresh weight of faeces in kg/day, DM_faeces is the dry weight of faeces in g DM/day (eq 12.26), the factor 0.135 is the dry matter content kg/kg fresh weight (an average of several trials)

NEW eq 12.26

$$DM\_faeces = Ash\_faeces + OM\_faeces$$

Where DM_faeces is the dry weight of faeces in g DM/day, Ash_faeces is the amount of fecal ash in g/day (eq 12.27a or 12.27b), OM_faeces is the amount of fecal organic matter in g/day (eq 12.28).

NEW eq 12.27a

$$Ash\_faeces = Ash\_intake \cdot 0.5$$

Where Ash_faeces is the amount of fecal ash in g/day, Ash_intake is the amount of dietary ash intake g/day, 0.5 is the default ash digestibility, which is used when the diet lacks concentration of the macro minerals Ca, P, Mg, K, Na, Cl, and S. the value 0.5 is an average from 145 observations.

When the macro minerals (Ca, P, Mg, K, Na, Cl, and S) are known in the diet this equation is used:

NEW eq 12.27b

$$Ash\_faeces = Ash\_intake - (Ca\_intake \cdot 0.45 + P\_intake \cdot 0.72 + Mg\_intake \cdot 0.21 + K\_intake \cdot 1.0 + Na\_intake \cdot 1.0 + Cl\_intake \cdot 0.92 + S\_intake \cdot 0.6)$$

Where Ash_faeces is the amount of fecal ash in g/day, Ash_intake is the amount of dietary ash intake g/day, Ca_intake is the amount of dietary calcium intake g/day, P_intake is the amount of dietary phosphorus intake g/day Mg_intake is the amount of dietary magnesia intake g/day, K_intake is the amount of dietary potassium intake g/day, Na_intake is the amount of dietary sodium intake g/day, Cl_intake is the amount of dietary chloride intake g/day and S_intake is the amount of dietary sulphur intake g/day. The factors 0.45, 0.21, 1.0 and 0.92 are digestibility factors from NASEM (2021), 0.21 is from equation Mg_intake_Min and 0.6 is from Gustafson and Olsson (2004)

NEW eq 12.28

$$OM\_faeces = DMI * 1000 - Ash\_intake - td\_OM$$

Where OM_faeces is the amount of fecal organic matter in g/day, DMI is the DM intake kg/day, Ash_intake is the amount of dietary ash intake g/day, td_OM is the total digested organic matter g/day (eq 7.59)

NEW eq 12.29

$$CP\_faeces = (CP\_intake - rd\_CP - sid\_CP + r\_mCP \cdot 0.15 + r\_outOM \cdot 0.03 \cdot 3 \cdot 0.4 + si\_outOM \cdot 0.025 + li\_mCP)$$

Where CP_faeces is the amount of fecal crude protein in g/day, CP_intake is the dietary crude protein intake g/day, rd_CP is the rumen degraded crude protein g/day (eq 7.8), sid_CP is the small intestine digested crude protein g/day (eq 7.36), r_mCP is the rumen microbial crude protein (eq 7.30), the factor 0.15 is the undigested share of the r_mCP, r_outOM is the dietary organic matter that passes out of rumen (7.36), the factor 0.03 refers to g endogenous CP per g OM flow, 3 and 0.4 is undigestible share of endogenous crude protein, si_outOM is the dietary organic matter that passes out of the small intestine (eq 7.47), the factor 0.025 is g endogenous crude protein per g OM flow, li_mCP is the large intestine microbial crude protein g/day (eq 7.50).

NEW eq 12.30

$$CFat\_faeces = (CFat\_intake - rd\_CFat - sid\_CFat + r\_mCFat \cdot (1 - 0.85 \cdot 0.65) + li\_mCFat)$$

Where CFat_faeces is the amount of fecal crude fat in g/day, CFat_intake is the dietary crude fat intake g/day, rd_CFat is the rumen degraded crude fat g/day (eq7.22), sid_CFat is the small intestine digested crude fat g/day (eq 7.41), r_mCFat is the rumen microbial crude fat g/day (eq 7.32), the factor 0.85 and 0.65 are the share of fatty acid g/g r_mCFat and digestibility factor of the fatty acids, respectively, li_mCFat is the large intestine microbial crude fat g/day (eq 7.51b).

NEW eq 12.31

$$CHO\_faeces = NDF\_faeces + ST\_faeces + RestCHO\_faeces$$

Where CHO_faeces is the amount of fecal carbohydrates in g/day, NDF_faeces is the amount of fecal neutral detergent fibre g/day (12.32), ST_faeces is the amount of fecal starch g/day (12.32), RestCHO_faeces is the amount of fecal rest fraction g/day (12.33).

NEW eq 12.32

$$NDF\_faeces = (NDF\_intake - rd\_NDF - lid\_NDF)$$

Where NDF_faeces is the amount of fecal NDF g/day, NDF_intake is the dietary NDF intake g/day, rd_NDF is the rumen degraded NDF g/day (eq 7.21), lid_NDF is the large intestine degraded NDF g/day eq 7.48) g/day.

NEW eq 12.33

$$ST\_faeces = (ST\_intake - rd\_ST - sid\_ST - lid\_ST + r\_mST - sid\_mST + li\_mST\ )$$

Where ST_faeces is the amount of fecal starch in g/day, ST_intake is the dietary starch intake g/day, rd_ST is the rumen degraded starch g/day (eq 7.14), sid_ST is the small intestine digested starch g/day (eq 7.40), lid_ST is the large intestine degraded starch g/day (eq 7.49), r_mST is the rumen microbial starch g/day (eq 7.30), sid_mST is the small intestine digested microbial starch g/day (eq 7.44), li_mST is the large intestine microbial starch, g/day, Equation 7.51c.

NEW eq 12.34

$$RestCHO\_faeces = (RestCHO\_intake - rd\_restCHO + r\_mRestCHO - r\_mRestCHO \cdot 0.75 + li\_mRestCHO)$$

Where RestCHO_faeces is the amount of fecal rest fraction in g/day, RestCHO_intake is the dietary rest fraction intake g/day, rd_RestCHO is the rumen degraded rest fraction, g/day Equation7.12; r_mRestCHO is the rumen microbial rest fraction, g/day, Equation 7.33b; 0.75 is the digestion of r_mRestCHO, g/g; li_mRestCHO is the large intestine microbial rest fraction, g/day, Equation 7.51d.

NEW eq 12.35

$$XX\_DMfaeces = (XX\_faeces)/(DM\_faeces) \cdot 1000$$

where XX_DMfaeces is the concentration of an analyte XX in faeces g/kg DM; XX_faeces is the amount of fecal analyte XX, g/day, Equation 12.27 to 12.34; DM_faeces is the amount of fecal dry matter g/day, Equation 12.26. Analyte XX is either ash, crude protein, crude fat, NDF, starch or rest fraction.

12.4 Emissions of climate gases from manure in housing stables, storage and spreading

Most of the equations is referred to IPCC (Dong et al., 2006)

NEW eq 12.36

$$OM\_bedding = kg\_bedding \cdot DM\_bedding/1000 \cdot (1000 - Ash\_DMbedding)/1000$$

where OM_bedding is the amount of bedding material of organic matter, kg/day, kg_bedding is the amount of bedding material per animal, kg/day; DM_bedding is the dry matter content of the bedding material g/kg, Ash_DMbedding is the ash content of the bedding material g/kg DM

default for kg_bedding in a loose housing system with slurry (slatted floor) is 0.1 kg straw/animal/day

default for kg_bedding in a loose housing system with deep litter is 8 kg straw/cow of all breeds but Jersey/day, 6 kg straw/Jersey cow/day, 2.7 kg straw/growing cattle of all breeds but Jersey/day, 2 kg straw/growing Jersey cattle/day

default for DM_bedding is the DM content in straw 850 g/kg

default for Ash_bedding is the ash content in straw 50 g/kg DM.

NEW eq 12.37

$$OM\_manure = OM\_faeces/1000 + OM\_bedding$$

where OM_manure is the organic matter of manure, kg/day; OM_faeces is the amount of fecal organic matter, g/day, Eq 12.28; OM_bedding is the amount of organic matter from bedding material, kg/day, Eq 12.36.

NEW eq 12.38

$$NEH\_N2O = N\_excreted/1000 \cdot factor\_1/100$$

where NEH_N2O is the nitrous gas net emission from manure in the housing stables, kg N/day; N_excreted is the amount of nitrogen excreted in urine and faeces, g/day, Eq. 12.11; factor_1 is the emission factor for N2O from manure management system, N2O, % of N (0.2 for slurry and 1 for deep litter).

NEW eq 12.39

$$NEH\_NH3 = N\_excreted/1000 \cdot factor\_1/100$$

where NEH_NH3 is the ammonia gas net emission from manure in the housing stables, kg N/day; N_excreted is the amount of nitrogen excreted in urine and faeces, g/day, Eq. 12.11; factor_1 is the emission factor for NH3 from manure management system, NH3, % of N (7 for slurry and 6 for deep litter).

New eq 12.40

$$NEH\_NOx = N\_excreted/1000 \cdot factor\_1/100$$

where NEH_NOx is the NOx gases net emission from manure in the housing stables kg N/day, N_excreted is the amount of nitrogen excreted in urine and faeces, g/day, Eq. 12.11; factor_1 is the emission factor for NOx from manure management system, NOx, % of N (0.2 for slurry and 1 for deep litter).

New eq 12.41

$$NEH\_N2 = N\_excreted/1000 \cdot factor\_1/100$$

where NEH_N2 is the dinitrogen net emission from manure in the housing stables kg N/animal/day, N_excreted is the amount of nitrogen excreted in urine and faeces, g/day, Eq. 12.11; factor_1 is the emission factor for N2 from manure management system, % of N in stable (0.6 for slurry and 3 for deep litter).

New eq 12.42

$$N\_manure = N\_excreted/1000 - (NEH\_N2O + NEH\_NH3 + NEH\_NOx + NEH\_N2)$$

where N_manure is the manure nitrogen stored at farm kg N/animal/day, N_excreted is the amount of nitrogen excreted in urine and faeces, g/day, Eq. 12.11; NEH_N2O, NEH_NH3, NEH_NOx and NEH_N2 are the net emissions from manure in the housing stables of nitrous gas, ammonia, NOx gases and dinitrogen respectively kg/day, Equations 12.38 to 12.41.

New eq 12.43

$$NES\_N2O = N\_manure \cdot factor\_1/100$$

where NES_N2O is the net emission of nitrous oxide from storage, kg N/day, N_manure is the amount of nitrogen entering the storage, g/day, Eq 12.42; factor_1 is the emission factor for N2O from manure management system, N2O, % of N (0.5 for slurry and 1 for deep litter).

New eq 12.44

$$NES\_NH3 = N\_manure \cdot factor\_1/100 \cdot (1 - factor\_2)$$

where NES_NH3 is the net emission of ammonia from storage, kg N/day, N_manure is the amount of nitrogen entering the storage g/day, , Eq 12.42; factor_1 is the emission factor for NH3 from manure management system, NH3, % of N (6 for slurry and 5 for deep litter), factor 2 is the effect of cover on storage (0.67 for slurry and 0.40 for deep litter).

New eq 12.45

$$NES\_NOx = N\_manure \cdot factor\_1/100$$

where NES_NOx is the net emission of NOx gases from storage, kg N/day, N_manure is the amount of nitrogen entering the storage, g/day, Eq 12.42; factor_1 is the emission factor for NOx from manure management system, NOx, % of N (0.5 for both slurry and deep litter).

New eq 12.46

$$NES\_N2 = N\_manure \cdot factor\_1/100$$

where NES_N2 is the net emission of dinitrogen from storage, kg N/day, N_manure is the amount of nitrogen entering the storage, g/day, Eq 12.42; factor_1 is the emission factor for N2 from manure management system, N2, % of N (1.5 for both slurry and deep litter).

New eq 12.47

$$MCF\_CH4 = factor\_1$$

Where MCF_CH4 is the methane conversion factor, %, factor_1 is 12.4 in slurry according to

(Mikkelsen et al., 2016) and 17 for deep litter (Dong et al., 2006).

New eq 12.48

$$GEH\_CH4 = OM\_manure \cdot 0.67 \cdot factorB0 \cdot MCF\_CH4/100$$

Where GEH_CH4 is the gross emission of methane from manure kg/day, 0.67 is the weight of $1m^3$ CH4 at 20 degrees Celsius, factor B0 is the maximal share of OM that can be CH4 (factorB0 is default 0.18, but is 0.24 for dairy cows of breeds RDM, DH, SLB, SRB, JER, NRF, ISL, CRSD or CRSJ): MCF_CH4 is the methane conversion factor, %, Equation 12.47.

New eq 12.49

$$N\_to\_field = N\_manure - (NES\_N2O + NES\_NH3 + NES\_NOx + NES\_N2)$$

where N_to_field is the amount of available manure nitrogen for application on fields kg N/day, N_manure is the amount of N in stored manure kg/day, Eq 12.42; NES_N20, NES_NH3, NES_NOx and

NES_N2 are the net emissions from storage of nitrous gas (Eq 12.43), ammonia (Eq 12.44), NOx gases (Eq 12.45) and dinitrogen (Eq 12.46), respectively, kg/day.

New eq 12.50

$$ERA\_N2O = N\_to\_field \cdot factor\_1/100$$

where ERA_N2O is the emissions of nitrous oxide related to manure application, kg N/d; N_to_field is the available manure nitrogen for field application, kg N/day, Eq 12.49; factor_1 is the emission factor for N2O from managed soils, (1 for both slurry and deep litter).

New eq 12.51

$$ERA\_NH3 = N\_to\_field \cdot factor\_1/100$$

where ERA_NH3 is the emissions of ammonia nitrogen related to manure application, kg N/d; N_to_field is the available manure nitrogen for field application, kg/day, Eq 12.49; factor_1 is the emission factor for NH3 from managed soils, (7.5 for slurry and 7 for deep litter).

New eq 12.52

$$ERA\_NOx = N\_to\_field \cdot factor\_1/100$$

where ERA_NOx is the emissions of NOx gases related to manure application, kg N/d; N_to_field is the available manure nitrogen for field application, kg/day, Eq 12.49; factor_1 is the emission factor for NOx from managed soils, (0.1 for both slurry and deep litter).

New eq 12.53

$$ERA\_N2 = N\_to\_field \cdot factor\_1/100$$

where ERA_N2 is the emissions of dinitrogen related to manure application, kg N/d; N_to_field is the available manure nitrogen for field application, kg/day, Eq 12.49; factor_1 is the emission factor for N2 from managed soils, (3 for both slurry and deep litter).

New eq 12.54

$$N\_fert\_repl = N\_to\_field \cdot factor\_1$$

where N_fert_repl is the fertilize replacement due to manure application, kg/d; N_to_field is the available manure nitrogen for field application, kg/day, Eq 12.49; factor 1 is the N utilization, (0.7 for slurry and 0.45 for deep litter).

New eq 12.55

$$P\_fert\_repl = P\_excreted/1000$$

Where P_fert_repl is the fertilize replacement due to manure phosphorus application, kg P/d; P_excreted is the excreted phosphorus in faeces and urine g/day Eq 12.17.

New eq 12.56

$$K\_fert\_repl = K\_excreted/1000$$

Where K_fert_repl is the fertilize replacement due to manure potassium application, kg K/d; K_excreted is the excreted potassium in faeces and urine g/day, Eq 12.20.

New eq 12.57

$$ExtraNO3N = N\_to\_field - N\_fert\_repl - (ERA\_N2O + ERA\_NH3 + ERA\_NOx + ERA\_N2)$$

where ExtraNO3N is extra nitrate nitrogen kg/day, N_to_field is the available manure nitrogen for field application, kg/d, Eq 12.49; N_fert_repl is the fertilize replacement due to manure application, kg/d, Eq 12.54; ERA_N2O, ERA_NH3, ERA_NOx and ERA_N2 are the emissions related to manure application, kg/day, of nitrous oxide, ammonia, NOx gases and dinitrogen, respectively, Equations 12.50 to 12.53.

New eq 12.58

$$AE\_N = N\_fert\_repl \cdot factor\_1$$

Where AE_N is the avoided emission from nitrogen fertilizer production, kg/d; N_fert_repl is the fertilize replacement due to manure application, kg/d, Eq 12.54; factor_1 is the carbon footprint for N artificial fertilizer production, (3.8 for both slurry and deep litter).

New eq 12.59

$$AE\_P = P\_fert\_repl \cdot factor\_1$$

Where AE_P is the avoided emission from phosphorus fertilizer production kg/d; P_fert_repl is the fertilize replacement due to manure application, kg/d, Eq 12.55; factor_1 is the carbon footprint for P artificial fertilizer production, (3.596 for both slurry and deep litter).

New eq 12.60

$$AE\_K = K\_fert\_repl \cdot factor\_1$$

Where AE_K is the avoided emission from potassium fertilizer production kg/d; K_fert_repl is the fertilize replacement due to manure application, kg/d, Eq 12.56; factor_1 is the carbon footprint for K artificial fertilizer production, (0.71 for both slurry and deep litter).

New eq 12.61

$$EA\_N2O = N\_fert\_repl \cdot factor\_1$$

Where EA_N2O is the emission of nitrous oxide from fertilizing at application, kg N/d; N_fert_repl is the fertilize replacement due to manure application, kg/d, Eq 12.54; factor_1 is the emission factor for N2O from artificial fertilizer application (0.01 for both slurry and deep litter).

New eq 12.62

$$EA\_NH3 = N\_fert\_repl \cdot factor\_1$$

Where EA_NH3 is the emission of ammonia from fertilizing at application, kg N/d; N_fert_repl is the fertilize replacement due to manure application, kg/d, Eq 12.54; factor_1 is the emission factor for NH3 from artificial fertilizer application (0.022 for both slurry and deep litter).

New eq 12.63

$$NEA\_NH3 = ERA\_NH3 \ + EA\_NH3 \cdot factor\_1$$

Where NEA_NH3 is the net emission of ammonia from fertilizing at application, kg N/d; ERA_NH3 is the emissions related to manure application of ammonia nitrogen, kg/d, Eq 12.51; EA_NH3 is the emission of ammonia from fertilizing at application kg N/d, Eq 12.62; factor_1 is 17/14 for both slurry and deep litter.

New eq 12.64

$$NEHS\_N2O = (NEH\_N2O + NES\_N2O) \cdot factor\_1$$

where NEHS_N2O is the net emission of nitrous oxide from housing and storage and application, kg N/day; NEH_N2O is the net emission of nitrous oxide from housing stable kg N/day Eq 12.38; NES_N2O is the net emission of nitrous oxide from storage, kg N/day Eq 12.43; factor_1 is 44/28 for both slurry and deep litter and is the ratio of N_2O and N_2O-N.

New eq 12.65

$$IE\_N2O = ((NEH\_NH3 - EA\_NH3\ ) \cdot factor\_1/100 + extraNO3N \cdot factor\_2) \cdot factor\_3$$

where IE_N2O is the indirect nitrous oxide emission from ammonia and leaching, kg N/day; NEH_NH3 is the net emission of ammonia from housing stable kg N/day; Eq12.39; EA_NH3 is the emission of ammonia from fertilizing at application, kg N/d, Eq12.62; ExtraNO3N is extra nitrate nitrogen kg/day from leaching when replacing artificial fertilizer with manure, Eq 12.59; factor_1 is the emission factor for NH3 from manure, (1), factor_2 the emission factor for NO3 from leached NO3-N (0.0075) and factor_3 is a conversion factor from N-N2O to N2O, (44/28 for both slurry and deep litter).

New eq 12.66

$$CO2e\_spread = 10 \cdot N\_to\_field/1000/0.0044 \cdot 0.37 + N\_to\_field \cdot 3.6/37 \cdot 2.81952$$

where CO2e_spread is the climate impact of fossil energy use when transporting, loading and spreading manure on fields, kg/day; N_to_field is the amount of available manure nitrogen for application on fields, kg/day, Eq 12.49; the factors 10 is the distance from the storage to the fields; 0.0044; 0.37 is the carbon footprint for using a wagon <10 tonnes, 3.6 is a constant for energy MJ per kg N in manure, 37 and 2.81952 is a constant for the carbon footprint for 1 L of fuel.

New eq 12.67

$$CO2e\_(fert\_avoid\ ) = AE\_N + AE\_P + AE\_K + CO2e\_spread$$

where CO2e_fert_avoid is the climate impact due to avoided fertilizer, kg CO2e/d; AE_N is the avoided emission from nitrogen fertilizer production kg/d, Eq 12.58; AE_P is the avoided emission from phosphorus fertilizer production kg/d, Eq 12.59; AE_K is the avoided emission from potassium fertilizer production kg/d, Eq 12.60, CO2e_spread is the climate impact of fossil energy use when transporting, loading and spreading manure on fields, kg/day, Eq 12.66.

New eq 12.68

$$Direct\_N2O = (ERA\_N2O + EA\_N2O) \cdot 44/28$$

where Direct_N20 is the direct emission of nitrous oxide kg N/day; ERA_N2O is the emissions of nitrous oxide related to manure application kg N/d, Eq 12.50; EA_N2O is the emission of nitrous oxide from fertilizing at application kg N/d, Eq 12.61; 44/28 and is the ratio of N_2O and N_2O-N

New eq 12.69

$$Indirect\_N2O = NEA\_NH3 \cdot 0.01 \cdot 44/28$$

where Indirect_N20 is the indirect emission of nitrous oxide kg N/day, NEA_NH3 is the net emission of ammonia from fertilizing at application, kg N/d, Eq 12.63; 0.01 is the emission factor and 44/28 and is the ratio of N_2O and N_2O-N.

New eq 12.70

$$CO2e\_HSspred = GEH\_CH4 \cdot 28.0 + (NEHS\_N2O + IE\_N2O + N2O\_direct + N2O\_indirect\ ) \cdot 265$$

CO2e_HSspred is the total emission of manure from housing, storage and spreading kg CO2e/day; GEH_CH4 is the gross emission of methane from manure kg/day, Eq 12.48; the factor 28 is the conversion factor from methane to carbon dioxide equivalents; NEHS_N2O is the net emission of nitrous oxide from housing and storage and application, kg/d, Eq 12.64; IE_N2O is the indirect nitrous oxide emission from ammonia and leaching kg N/day, Eq 12.65; Direct_N20 is the direct emission of nitrous oxide kg N/day, Eq 12.68; Indirect_N2O is the indirect emission of nitrous oxide kg N/day, Eq 12.69; the factor 265 is the conversion factor from nitrous oxide to carbon dioxide equivalents.

Dairy cows on deep litter are assumed to have 60% area of deep bedding and 40% slurry, whereas to growing cattle on deep litter are assumed to have 100% area of deep litter

New eq 12.71

$$CO2e\_feeds\ = \sum_i (DMI_i \cdot CO2e\_feedstuff_i)/1000$$

where CO2e_feeds is the sum of climate impact from feedstuffs, kg CO2e/day; DMI_i is the dry matter intake of the i'th=1… feedstuff, kg/day; $CO2e\_feedstuff_i$ is the emission of the i'th feedstuff in connection with cultivation, processing and transport in g/kg DM (Mogensen et al., 2018; Henriksson et al., 2019; Woodhouse, 2019; Flysjö et al., 2008) and Eq 12.82.

New eq 12.72

$$CO2e\_soil\ = \sum_i (DMI_i \cdot C2Oe\_soil\_feedstuff_i)/1000$$

where CO2e_soil is the sum of climate impact from carbon sequestration kg CO2e/day; DMI_i is the dry matter intake of the i'th=1… feedstuff, kg/day; $C2Oe\_soil\_feedstuff_i$ is the carbon sequestration of the i'th feedstuff in connection with feed cultivation, g/kg DM (Mogensen et al, 2018) and Eq 83.

New eq 12.73

$$CO2e\_animalfeedsoilmanure = CO2e\_animal + CO2e\_feeds + CO2e\_soil + CO2e\_HS\_spred$$

where CO2e_animalfeedsoilmanure is the sum of emission from enteric methane, cultivation of feed and manure handling, kg CO2e/day; CO2e_animal is the emissions of the enteric methane in kg CO2e/day, Eq 12.24; CO2e_feeds is the climate impact from feeds in kg CO2e/day, Eq 12.71; CO2e_soil is the carbon sequestration in connection with feed cultivation, kg CO2e/day, Eq 12.72; CO2e_HSspred is the total emission of manure from housing, storage and spreading kg CO2e/animal/day, Eq 12.70.

New eq 12.74

$$CO2e\_(animalfeedsoilmanur\_ECM\ ) = CO2e\_animalfeedsoilmanur * 1000/ECM$$

where CO2e_animalfeedsoilmanure is the sum of emission from enteric methane, cultivation of feed and manure handling per kg energy corrected milk, g CO2e/kg ECM; CO2e_animalfeedsoilmanure is the sum of emission from enteric methane, cultivation of feed and manure handling, kg CO2e/day, Eq 12.73; ECM is energy corrected milk kg/day, Eq 3.2.

New eq 12.75

$$CO2e\_animalfeedsoilmanure\_ADG = \frac{CO2e\_animalfeedsoilmanure \cdot 1000}{ADG/_{1000}}$$

where CO2e_animalfeedsoilmanure is the sum of emission from enteric methane, cultivation of feed and manure handling, g CO2e/kg ADG; CO2e_animalfeedsoilmanure is the sum of emission from enteric methane, cultivation of feed and manure handling, kg CO2e/day, Eq 12.73; ADG is the average daily body weight gain, g/day, Eq 3.6.

12.4.2 Emissions in connection with grazing and pasture management

Equations derives from IPCC (De Klein et al., 2006).

New eq 12.76

$$NEP\_N2O = N\_excreted/1000 \cdot 2/100$$

where NEP_N2O is the net emission of nitrous oxide at pasture kg N/day; N_excreted is excreted nitrogen in urine and faeces, g/day, Eq 12.11; 2% of the excreted N is emitted as nitrous oxide

New eq 12.77

$$NEP\_NH3 = N\_excreted/1000 * 7/100$$

where NEP_NH3 is the net emission of ammonia at pasture kg N/day; N_excreted is excreted nitrogen in urine and faeces, g/day, Eq 12.11; 7 % of the excreted N is emitted as ammonia

New eq 12.78

$$NEP\_CH4 = OM\_manure * 0.67 * 0.24 * 1/100$$

where NEP_CH4 is the net emission of methane from manure at pasture kg /day; OM_manure is the organic matter in the manure g/day, Eq 12.37; 0.67 is the weight of $1m^3$ CH4 at 20 degrees Celsius, , 0.24 is the maximal share of OM that can be converted to CH4, 1/100.

New eq 12.79

$$TEP\_N2O = NEP\_N2O * 44/28 + NEP\_NH3 * 44/28 * 1/100$$

Where TEP_N20 is the total emission of nitrous oxide at pasture kg/day, NEP_N2O is the net emission of nitrous oxide at pasture kg N/day, Eq 12.76; NEP_NH3 is the net emission of nitrous oxide at pasture kg N/day, Eq 12.77; 44/28 is the factor for converting nitrogen oxide-N (N_2O-N) to N_2O,1/100 is the emission factor for nitrous oxide (N2O)

New eq 12.80

$$CO2e\_manurepasture = 265 * TEP\_N2O + 28 * NEP\_CH4$$

Where CO2e_manurepasture is the manure emission of carbon dioxide equivalents (CO2e) when the animal is on pasture, kg/day; TEP_N20 is the total emission of nitrous oxide at pasture kg/day, Eq 12.78; NEP_CH4 is the net emission of methane when the animal is on pasture, kg/d, Eq 12.77; 265 is the conversion factor from nitrous oxide to CO2e and 28 is the conversion factor from methane to CO2e.

New eq 12.81

$$CO2e\_HSspredpasture8h = 0.6667 \cdot CO2e\_HSspred + 0.3333 \cdot CO2e\_manurepasture$$

Where CO2e_HSspredpasture8h is manure emission of carbon dioxide equivalents (CO2e) corresponds to a lactating dairy cow outdoors for 8 hours per day and indoors 16 hours, kg/d; CO2e_HSspred is manure emissions of CO2e indoor, kg/day, Eq.12.70; CO2e_manurepasture is manure emission of CO2e when a cow is on pasture, kg/d, Eq 12.80; 0.6667 corresponds to two thirds of a day and 0.3333 is one third of a day.

New eq 12.82

CO2e_feedstuff

Ley defined as PS>11 and ST<50

Maize defined as 7>PS>11 and ST>150

Fodder beets PS<8 RestCHO>300

If value exists in the input typed CO2e in the feedstuff table, then:

$$CO2e\_feedstuff = CO2e\_feedstuff\_typed$$

If ley, maize or fodder beets have values on Yield, ManureN and FertilizerN in the feedstuff table then:

$$CO2e_{feedstuff} = ((FertilizerN - FtzNcovercrop) \cdot 3.8 + (FertilizerN - FtzNcovercrop) \cdot 0.01 \cdot 44/28 \cdot 265 + ManureN \cdot 0.01 \cdot 44/28 \cdot 265 + CO2e\_other + CropresidueN \cdot 0.01 \cdot 44/28 \cdot 265 - PrecedingcropN \cdot 3.8 - PrecedingcropN \cdot 0.01 \cdot 44/28 \cdot 265) \cdot 1000/Yield$$

Where: CO2e_calc is the climate impact of cultivating the crop (g CO2e/kg DM); Yield is the yearly harvest yield of the crop (kg DM/ha); FertilizerN is the input of nitrogen application from fertilizer (kg N/ha).

FtzNcovercrop is the amount of N used for cover crop (kg N/ha),

For ley $FtzNcovercrop = 0$

For maize $FtzNcovercrop = 15$

For fodder beets $FtzNcovercrop = 0$.

ManureN is the input of nitrogen application from manure (kg/N/ha).

CO2e_other is climate impact of other things. That includes climate impact of N_2O from ammonia emissions, irrigation, nitrate leakage, liming, pesticides, P and K fertilizer and fuel (kg CO2e/ha).

For ley $CO2e\_other = 1036$

For maize $CO2e\_other = 1011 - 88$

For fodder beets $CO2e\_other = 906$

CropresidueN is the nitrogen in the crop residue (kg N/ha)

For leys $cropresidueN = (Yield \cdot 0.3 \cdot 0.025 + (Yield + Yield \cdot 0.3) \cdot 0.8 \cdot 0.016)/3$

For maize $cropresidueN = (Yield \cdot 0.2 \cdot 0.007) + 25 + (Yield + Yield \cdot 0.2) \cdot 0.22 \cdot 0.009 + 15$

For fodder beets $cropresidueN = (Yield \cdot 0.25 + Yield \cdot 0.17) \cdot 0.014 + (Yield + Yield \cdot 0.17) \cdot 0.1 \cdot 0.0118$

$PrecedingcropN$ *is the preceding nitrogenous effect* of the crop (ley, maize or fodder beets) (kg N/ha) according to (Hvid, 2022). Corresponds to saved fertilizing

For ley precedingcropN = 67/3

For maize precedingcropN = 0

For fodder beets precedingcropN = 3

Where: 3.8 is the climate impact of manufacturing fertilizer nitrogen (kg CO_2e/kg N) (Hvid, 2022); 0.01 is the emission factor for nitrous oxide (N_2O) (IPCC, 2006); 44/28 is the factor for converting N_2O-N to N_2O (IPCC, 2006); 265 is the climate impact factor of nitrous oxide (kg CO_2e/kg N_2O) according to IPCC (2014); 0.3 of yield corresponds to the amount of residue above the soil of ley yield (IPCC, 2006 value for leys, modified by Hvid, 2022); 0.025 is the N content in above-ground crop residues from ley (grass-clover mixes) (kg N/kg DM) (IPCC, 2006); 0.8 is the ratio between below-ground residues to above-ground residues for leys (IPCC, 2006); 0.016 is the N content in below-ground crop residues from ley (grass-clover mixes (kg N/kg DM) (IPCC, 2006); /3 corresponds to 3 years which is the recommended cultivation time of leys; 0.2 of yield corresponds to the amount of residue above the soil of maize yield (IPCC, 2006); 0.007 is the assumed N content in above-ground crop residue from maize (kg N/kg DM) (Modified by Hvid, 2022 from IPCC 2006 from maize kernels 0.006); 25 is the assumed N of above-ground crop residue from the cover crop after maize (kg N/ha) (Hvid, 2022); 0.22 is the ratio of below-ground residues to above-ground biomass for maize (Modified from IPCC, 2006 by Hvid, 2022); 0.009 is the assumed N content in below-ground crop residue from grains (kg N/kg DM) (Modified by Hvid, 2022 from IPCC, 2006); 15 is an assumed amount of N from crop residue below-ground from the cover crop after maize (kg N/kg ha) (Hvid, 2022); 0.25 is the assumed proportion residue above the soil of fodder beet yield (Hvid, 2022); 0.17 of fodder beet yield corresponds to the amount of fodder beet top (Hvid, 2022); 0.014 is the assumed N content in crop residue above-ground from fodder beets (kg N/kg DM) (Modified by Hvid, 2022 from IPCC, 2006); 0.1 of yield and top corresponds to DM below the ground for fodder beets (IPCC, 2006); 0.0118 is the assumed N content in crop residue below-ground from fodder beets (kg N/kg DM) (Modified by Hvid, 2022 from IPCC, 2006); 1000 is the factor to convert kg to gram

New eq 12.83

CO2e_soil_feedstuff

Ley defined as PS>11 and ST<50

Maize defined as 7>PS>11 and ST>150

Fodder beets PS<8 RestCHO>300

If value exists in the input typed C2Oe_soil in the feedstuff table, then:

$$C2Oe\_soil\_feedstuff = C2Oe\_soil\_feedstuff\_typed$$

If ley, maize or fodder beets have values on Yield, ManureN and FertilizerN in the feedstuff table then:

$$C2Oe\_soil\_feedstuff = -(ManureN \cdot 8 + CropresidueC - 5700) \cdot 0.097 \cdot 44/12 \cdot 1000/Yield$$

Where: C2Oe_soil_feedstuff is the climate impact of Carbon sequestration (g CO2e/kg DM) for a feedstuff; Yield is the yearly harvest yield of the crop (kg DM/ha); ManureN is the input of nitrogen application from manure (kg/N/ha); 8 is the assumed carbon content of the manure (kg C/kg N)

(Hvid, 2022); CropresidueC is the carbon contribution from the residue from the crop and from *e*.g., roots

for leys $CropresidueC = 1000 + 4500$

for maize $CropresidueC = (Yield \cdot 0.2 + (Yield + Yield \cdot 0.2) \cdot 0.22) \cdot 0.45 + 450$ (kg C/ha)

For fodder beets $CropresidueC = (Yield \cdot 0.25 + Yield \cdot 0.17 + (Yield + Yield \cdot 0.17) \cdot 0.1) \cdot 0.45$ (kg C/ha)

Where: 1000 is the factor to convert kg to gram (g/kg); 0.097 is the global warming potential for 100 years GWP100 (Kristensen et. al., 2021); 44/12 is the conversion factor from CO_2-C to CO_2 (IPCC, 2006); 5700 is the expected C-balance value for ley, maize and fodder beets on land that has been used for cattle for a long time (kg C/ha) (Hvid, 2022); 1000+4500 is fixed factors of root biomasses after ley, decay and rhizome (kg C/ha) (Hvid, 2022); 0.3 of yield corresponds to the amount of residue above soil of ley yield and (IPCC, 2006 modified by Hvid, 2022); 0.2 of yield corresponds to the amount of residue above the soil of maize yield (IPCC, 2006); 0.22 is the ratio of below-ground residues to above-ground biomass for maize (Modified from IPCC, 2006 by Hvid, 2022); 0.45 is the carbon content of the plant (kg C/kg DM) (valid for all plant dry matter, Hvid, 2022); 450 fixed value of total C input for a cover crop after maize (kg C/ha) (Hvid, 2022); 0.25 is the assumed proportion residue above the soil of fodder beet yield (Hvid, 2022); 0.17 of fodder beet yield corresponds to the amount of fodder beet top (Hvid, 2022); 0.1 of yield and top corresponds to DM below the ground for fodder beets (IPCC, 2006).

New eq 12.84

If value exists in the input typed Areal in the feedstuff table, then:

$Areal = Areal\_typed$

If a feed has values on Yield in the feedstuff table, then:

$Areal = 10000/Yield$

Where: Areal is the land requirement (m^2/kg DM); Yield is the harvest yield (kg DM/ha); 10000 is the conversion factor from hectare to m^2 (m^2/ha).

Feed additives for reducing enteric methane emission

New eq 12.85

$$reduction\_NO3 = -1.03 \times (\sum\_i 〖DMI〗\_i \times 〖NO3〗\_i 〗)/(\sum\_i 〖DMI〗\_i)$$

Where: reduction_NO3 is the reduction effect of nitrate on enteric methane emission, %; DMI_i is the dry matter intake of the 1…n'th feedstuff, kg/day, $NO3_i$ is the content of nitrate in the 1…n'th feedstuff, g/kg DM. When the nitrate concentration is above 25 g per kg DM then the value in the equation is 25

New eq 12.86

$$reduction\_3NOP = -40.51 - 0.1986 \times \frac{\sum_i DMI_i \times 3NOP_i}{\sum_i DMI_i} + 0.09672 \times \frac{\sum_j DMI_j \times NDF_j}{\sum_i DMI_i}$$

Where: reduction_3NOP is the reduction effect of trinitrooxypropanol (3NOP) on enteric methane emission, %; DMI_i is the dry matter intake of the 1…n'th feedstuff, $3NOP_i$ is the content of 3NOP in the 1…n'th feedstuff milligram/kg DM; DMI_j is the dry matter intake of the 1…n'th roughage, NDF_j is the content of NDF in the 1…n'th roughage, g/kg DM. When the 3NOP concentration in the diet is below 40 milligram per kg DM then the value in the equation is 0; when the 3NOP concentration in the diet is above 80 milligram per kg DM then the value in the equation is 80; when roughage NDF is below 150 g/kg DM in the diet then the value in the equation is 150.

New eq 12.87

reduction_CH4 = reduction_NO3 or reduction_CH4 = reduction_3NOP

where reduction_CH4 is the most negative effect of one feed additive of two (ore several) on enteric methane emission, %; reduction_NO3 is the negative effect of the feed additive nitrate NO3, %, eq 12.85; reduction_3NOP is the negative effect of the feed additive tri-nitrooxypropanol (3NOP), %, eq 12.86. The effect is not accumulative for several feed additives. The effect cannot be a positive value.

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Chapter 13. Standard feed values

Eq 13.1. $RLI_{std} = \frac{DMI_{std} \cdot 280}{DMI_{std} \cdot 370}$

Table 13.1 Fixed values

Parameter	8 kg DMI	20 kg DMI
Passage rate for NDF in roughage, %/h	0.795600	1.73671

The calculation of standard feed value of essential amino acids Histidine (His_{20}), Lysine (Lys_{20}) and Methionine (Met_{20}) are calculated as eq 8.12 on basis of the fixed values in table 13.1 %of AAT

NEW eq.13_10 $Histidine_{20} = sid\_His + sid\_mHis + sid\_eHis$

Where Histidine20 is the standard feed value of Histidine (g/kg DM), sid_His is the rumen undegraded histidine absorbed in the small intestine (g/day) described in eq 7.39, sid_mHis is the histidine absorbed in the small intestine which is derived from microbial CP (g/day) described in eq 7.42 and table 7.2, sid_eHis is the histidine absorbed in the small intestine derived from endogenous CP (g/day) described in eq 7.46 and table 7.2. The fixed values in table 13.1 must be used.

NEW eq.13_11 $Ly\,sin\,e_{20} = sid\_Lys + sid\_mLys + sid\_eLys$

Where Lysine20 is the standard feed value of Lysine (g/kg DM), sid_Lys is the rumen undegraded lysine absorbed in the small intestine (g/day) described in eq 7.39, sid_mLys is the Lysine absorbed in the small intestine which is derived from microbial CP (g/day) described in eq 7.42 and table 7.2, sid_eLys is the lysine absorbed in the small intestine derived from endogenous CP (g/day) described in eq 7.46 and table 7.2. The fixed values in table 13.1 must be used.

NEW eq.13_12 $Methionine_{20} = sid\_Met + sid\_mMet + sid\_eMet$

Where Methionine20 is the standard feed value of Methionine (g/kg DM), sid_Met is the rumen undegraded methionine absorbed in the small intestine (g/day) described in eq 7.39, sid_mMet is the Methionine absorbed in the small intestine which is derived from microbial CP (g/day) described in eq 7.42 and table 7.2, sid_eMet is the methionine absorbed in the small intestine derived from endogenous CP (g/day) described in eq 7.46 and table 7.2. The fixed values in table 13.1 must be used.

NEW eq.13_13 $NDFD20 = \frac{rd\_NDF + lid\_NDF}{NDF} \cdot 100$

Where NDFD20 is the standard feed value of NDF total tract digestibility (%) at 20 kg DMI, rd_NDF is the rumen degraded NDF (g/day) described in eq 7.21, lid_NDF is the degraded NDF in the large intestine (g/day) described in eq 7.48, NDF is the content of NDF in the feedstuff (g/kg DM). The fixed values in table 13.1 must be used.

Alvarez *et a*l (2021) developed a static empirical model for estimation of net energy content of compound feeds in a dynamic feeding system using NEL20 values calculated by the NorFor model. The estimation model was updated by Alvarez *et al* (2022).

New eq 13.4 $NEL20_{comp} = 5.523 - 0.0327 * \frac{\mathrm{Ash}}{10} + 0.0251 * \mathrm{DOM} + 0.0146 * \frac{\mathrm{CPcorr}}{10} + 0.0992 * \frac{\mathrm{CFat}}{10} - 0.0524 * \frac{\mathrm{NDF}}{10}$

Where NEL20_comp is net energy of lactation at 20 kg DMI/d (MJ/kg DM) for compound feed when analysed (MJ net energy per kg DM); Ash is the ash content (g/kg DM); DOM is the digested organic matter (% of DM; eq 13.5); CPcorr is the corrected crude protein (eq 4.4) based on analysed crude protein and added urea reported by the manufacturer; CFat is the analysed crude fat (g/kg DM); and NDF is the analysed neutral detergent fibre (g/kg DM).

New eq 13.5 $DOM = (1000 - Ash)/10 * EFOS/100$

Where DOM is the digested organic matter (% of DM)

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Chapter 14. System evaluation

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