

Equation changes since NorFor 2011 (EAAP No.130)

2014-12-23, 2016-09-15, 2016-10-15; 2017-03-09; 2017-12-28 (iNDF₅₀₄); 2019-09-16

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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

NEW eq.4.8

$$IV = (C18_1 \cdot 89.8 + C18_2 \cdot 2 \cdot 89.8 + C18_3 \cdot 3 \cdot 89.8 + C20_5 \cdot 5 \cdot 81.7 + C22_6 \cdot 6 \cdot 75) / 100$$

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 concentration of the fatty acids 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

$$kdST = (r_{kpc} \times rSTD) / (1000 - rSTD)$$

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)

$$iNDF = [(NDF]_{288} / NDF \times 1000$$

Eq 5.27b

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

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

Eq 5.27c

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

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

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

$$iNDF = 1000 \times 20 / NDF$$

$$iNDF_{288} = 1000 - ((1000 - iNDF_{504}) \times 0.997 - 15.5)$$

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. Anim Feed Sci Tech 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

$$pdNDF_{corr} = 1000 - iNDF$$

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

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

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 NH₃N 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 NH₃N 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 NH₃N is less than 50 g/kg N.

Chapter 7 Digestion and metabolism in the gastrointestinal tract

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 and 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)

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

$$NEL_dep = BW_change_mobdep \cdot 31.0$$

$$\text{If } change_BCS > 0 \text{ then } NEL_dep = change_BCS \cdot kg_BCS \cdot 31.0$$

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

Eq 9.18

$$NEL_mob = -1 \cdot BW_change_mobdep \cdot 24.8$$

$$\text{If } change_BCS < 0 \text{ then } NEL_mob = change_BCS \cdot kg_BCS \cdot 24.8$$

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

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

$$b = 0.04 + 0.05 \cdot BW_{mob} - 0.305 \cdot (BCS_{calv} - BCS_{end}) \cdot 2$$

NEW eq 9.19 c

$$c = \frac{b}{2.4207 / -7.3955} + 0.151 \cdot (-(BCS_{calv} - BCS_{end}) \cdot 2 \cdot 2.55)$$

NEW eq 9.19 d

$$BW_{change_mobdep} = \left(\frac{BW_{mob} + b \cdot \sqrt{DIM} \cdot \ln(DIM)}{+ c \cdot (\ln(DIM))^2} \right) - \left(\frac{BW_{mob} + b \cdot \sqrt{(DIM-1)} \cdot \ln(DIM-1)}{+ c \cdot (\ln(DIM-1))^2} \right)$$

If DIM=1

$$BW_{change_mobdep} = \left(\frac{BW_{mob} + b \cdot \sqrt{DIM+2.1} \cdot \ln(DIM+2.1)}{+ c \cdot (\ln(DIM+2.1))^2} \right) - \left(\frac{BW_{mob} + b \cdot \sqrt{(DIM+2-1)} \cdot \ln(DIM+2-1)}{+ c \cdot (\ln(DIM+2-1))^2} \right)$$

$$NEW \text{ Eq 9.19d } BW_{dep} = a \cdot \left(1 + 2 \cdot \frac{BCS_{end} - 3.5}{3.5} \right)$$

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

$$\text{Eq 9.22 } AAT_N_maint = EUN + Scurf + MFP$$

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.

$$\text{Eq 9.22b } EUN = \frac{2.75 \cdot BW_cur^{0.5}}{0.67}$$

$$\text{Eq 9.22c } Scurf = \frac{0.2 \cdot BW_cur^{0.6}}{0.67}$$

$$\text{Eq 9.22d } MFP = \frac{r_outOM \cdot 0.03 \cdot 0.5 \cdot 3 \cdot 0.4}{0.67} + si_outOM \cdot 0.025 \cdot 0.5$$

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 AAT_N 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.

$$\text{Eq 9.26 } Avail_AAT_N = AAT_N - AAT_N_maint - AAT_N_gain - AAT_N_gest + AAT_N_mob - AAT_N_dep$$

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)

$$\text{Eq 9.38 } AAT_NEG_Min = \frac{(1.88 - 0.00176 \cdot BW_cur - 0.2283 \cdot ADG / 1000 + 0.0000019014 \cdot BW_cur^{1.83})}{0.03821 \cdot 2 - 0.000000016 \cdot 5 \cdot 14^4} - 1$$

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

9.8.1 Macro minerals

Eq 9.45 for lactating cows of beef breeds $Ca_maint = 0.0154 \cdot BW / 0.5$ according to NRC 2000 (beef)

Eq 9.50 for lactating cows of beef breeds $P_maint = 0.016 \cdot BW / 0.7$ according to NRC 2000 (beef)

Eq 9.61 for lactating cows of beef breeds $Na_maint = 0.015 \cdot BW / 0.9$ according to NRC 2000 (beef)

Eq 9.65 for lactating cows of beef breeds $K_maint = (0.038 \cdot BW + 2.6 \cdot 0.0167 \cdot BW) / 0.9$ according to NRC 2000 (beef)

Eq 9.47; 9.52; 9.57, 9.62, 9.67 and 9.72 requirements for gain is valid for both 1st and 2nd calvers

9.8.2 Micro minerals

Table 9.15. Zn_DM_Min=30; Se_DM_Min=0.1 for cows of beef breeds (according to NRC 2000)

9.7 Fatty acids

NEW Eq 9.77 $IV_DM_Max = 45$

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 9.78 $His_AAT_Min = 2.2$

NEW Eq 9.79 $Lys_AAT_Min = 6.4$

NEW Eq 9.80 $Met_AAT_Min = 2.2$

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.

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
1 st 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
1 st calvers JER	2.50	0.134	-0.0005	0.06	0.110	360	0.006	0.4
Older JER	2.70	0.134	-0.0002	0.03	0.110	405	0.006	0.4
1 st 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.

$$Eq\ 10.8\ FV_MR = 1.453 - \frac{2.530}{1 + \exp\left(\frac{0.466 - FV_r}{0.065}\right)}$$

Eq 10.9, 10.10, 10.12, 10.13

$$IC_animal = (factor_1 \cdot BW_cur + factor_2 \cdot ADG_LW) \cdot IC_exercise \cdot IC_gest$$

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_exercise 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

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

$$CH4 = 1.39 \cdot DMI - 0.091 \cdot FA_DM$$

Where $CH4$ is enteric methane production (MJ per day), DMI is the dry matter intake (kg per day) and FA_DM the fatty acid concentration in the ration (g/kg DM)

Enteric methane production of growing cattle

$$CH4 = \frac{(-0.046 \cdot conc_share + 7.1379) \cdot GE}{100}$$

Where $CH4$ is enteric methane production (MJ per day), $conc_share$ is share of concentrate in the ration (% of DM) and GE is the Gross energy in the ration (MJ)

NEW eq 12.22

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

Where Ym is the efficiency (%), $CH4$ is the enteric methane production (MJ/day) and GE is the gross energy intake (MJ/day)

NEW eq 12.23

$$CH4_g = \frac{CH4}{55.65} \cdot 1000$$

Where $CH4_g$ is the enteric methane production in gram (g/day), 55.65 is the conversion factor from ICCP

NEW eq 12.24

$$CO2e = \frac{CH4_g \cdot 25}{1000}$$

Where CO₂e is the carbon dioxide equivalents (kg /day) from CH₄_g enteric methane production (g/day) and the conversion factor 25 (ICCP)

Chapter 13. Standard feed values

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

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 (His₂₀), Lysine (Lys₂₀) and Methionine (Met₂₀) are calculated as eq 8.12 on basis of the fixed values in table 13.1 %of AAT

$$\text{NEW eq.13}_{10} \quad \text{Histidine}_{20} = sid_His + sid_mHis + sid_eHis$$

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.

$$\text{NEW eq.13}_{11} \quad \text{Lysin}_{20} = sid_Lys + sid_mLys + sid_eLys$$

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.

$$\text{NEW eq.13}_{12} \quad \text{Methionine}_{20} = sid_Met + sid_mMet + sid_eMet$$

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.

$$\text{NEW eq.13}_{13} \quad \text{NDFD}_{20} = \frac{rd_NDF + lid_NDF}{NDF} \cdot 100$$

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.

Chapter 14. System evaluation

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