26. januar, 2006

"NorFor Dyr i vekst"

- en test af fordøjelsesmodellen i NorFor Plan til ungdyr samt en sammenligning af energibehov og energitilførsel beregnet efter nationale systemer og NorFor Plan

Summary

The overall purpose of this work is to develop a new Nordic feed evaluation tool for young stock, i.e. heifers, bulls and steers with main focus on dairy breeds but also including beef breeds. The aims of this report were to: 1) evaluate the digestion model for cows in NorFor Plan in order to decide whether it could be used for young stock 2) make the necessary changes in the digestion model for cows in order to use it as the digestion model for young stock 3) compare different national systems that calculates energy requirements for young stock.

The digestion model shows reasonable results when typical diets fed to young stock in the Nordic countries were tested in NorFor Plan. Generally, NorFor overestimates the energy content in Norwegian and partly Danish diets, while the Swedish diets consistently underestimated energy supply compared to the systems used in the respective countries today. The tests of these diets in NorFor Plan led to changes in the equation for microbial protein synthesis because it was evaluated that the calculated synthesis was too low at high levels of starch+sugar in the diet. Further, it was concluded that the digestibility of NDF was too low at high levels of starch+sugar in the diet. This led to changes in the equation for rumen passage rate of NDF in roughage and the equation that determines the influence of "vombelastning" on the rumen degradation rate of NDF. Thus, NorFor Plan now calculates a higher NDF-digestibility when the diet has a high content of starch+sugar in the diet.

There is a quite good agreement between the different national systems in terms of net energy requirements depending on live weight and daily gain for bulls, heifers and steers. However, relatively large differences between systems do occur at relatively high daily gains. The Danish and Swedish systems have higher energy requirements than the other systems at high daily gains or high live weights. The French system seems to be the most robust, but the French system is also the most complex because it needs input on fat and protein retention and the dietary ME/GE ratio, i.e. the utilisation coefficient of ME to NE is unknown until the diet is defined and thereby also the NE supply from the diet. This is similar to what is used in the NorFor Plan Dairy cow model. The Nordic systems only need information on live weight and daily gain. The Dutch system is more or less a copy of the French system. We need to do some more testing of these energy systems in relation to production/experimental data, but it is concluded that the French system has the greatest potential for "NorFor Dyr i Vekst".

Abbreviations:
AA: Aberdeen Angus
CHA: Charolais
DH: Danish Holstein
DJ: Danish Jersey
HRF: Hereford
LIM: Limousine
NRF: Norsk Rødt Fe
PIE: Pietmontese
RD: Red Danish
SIM: Simmenthal
SLB: Svensk Laglands Buskap
SRB: Svensk Rød Buskap
DTV: Daglig tilvækst

Words that differs in the Nordic languages:

Dansk	Svensk	Norsk
Byg	Korn	Bygg
FE	Foderenhet	Fôrenhet
Foderrationer	Foderstater	Fôrrasjoner
Fordøjelig	Smältbar	Fordøyelig
Korn	Spannmål	Korn
Kvier	Kvigor	Kviger
Stivelse	Stärkelse	Stivelse
Stude	Stutar	Kastrater
Træstof	Växttråd	Trevler
Tyre	Tjurar	Okser

Baggrund
Ét nyt Nordisk fodervurderingssystem til malkekøer tages i brug i efteråret 2006 i Norge, Sverige, Island og Danmark. Det er imidlertid også planen at få udviklet et Nordisk fodervurderingssystem til ungdyr (kvier, tyre & stude), som kan tages i brug i efteråret 2007.

Formål
I køernes nye fodervurderingssystem indgår en fordøjelsesmodel, som også gerne skulle kunne anvendes i ungdyrenes system. Man kan teste om køernes model giver fornuftige resultater for ungdyrene ved at sammenligne en foderrations energiværdi beregnet via NorFor med det nationale energivurderingssystem (Fe_m i Norge og Island; MJ omsættelig energi i Sverige; Fe i Danmark). Endvidere er formålet at studere fordøjelses-karakteristika afhængig af fodermidlerne og foderniveauet og vurdere om der er behov for tilpasninger af køernes fordøjelsesmodel til Dyr i vekst. Desuden er formålet at sammenligne forskellige landes energisystemer og behov til ungdyr, som skal være udgangspunkt for valg af energisystem.

Comparison of energy requirements for young stock in different countries

The purpose is to establish a background for choosing an energy system for young stock in NorFor Plan. The ambition is to use a common set of equations that can be used in calculation of energy requirements to young stock (heifers, bulls, steers) of both dairy and beef breeds.

In order to compare different national energy systems for young stock, the net energy requirement for bulls, steers and heifers of different breeds was calculated depending on live weight and daily gain. This comparison is shown Table 1-5 and the calculations were carried out in a young stock workshop held in Denmark in August and November 2006. The equations used for the different types of animals are shown below each of the Tables.

Table 1. A comparison of net energy requirements (MJ/d) calculated from different national systems to bulls of large dairy breeds depending on live weight (LW) and average daily live weight gain (DLWG).

LW (kg)	DLWG (g/d)	NO (MJ/d)	DK (MJ/d)	SE/UK (MJ/d)	French (MJ/d)	Dutch (MJ/d)	Average (MJ/d)
200	800	26,8	22,9	28,4	26,9	24,4	25,9
	1000	30,2	28,6	32,2	29,0	26,1 *29,3*[4]	29,2
	1200	33,7 (15,6)[3]	34,3	36,7 (17,9)	31,3 (19,6)	27,9 (17,6) *32,8*[4]	32,8
	1400	37,1	40,0	42,1	34,0	31,4 *36,2*[4]	36,9
350	1000	41,4	41,9	45,4	42,0	38,7 *42,1*[4]	
	1600	51,7	67,1	66,6	52,5	51,1 *56,6*[4]	57,8
500	800	48,2	49,3	52,7	50,0	47,3	49,5
	1000	51,6 (30,9)[3]	61,6	58,6 (36,2)	53,8 (38,9)	50,4 (34,9) *55,5*[4]	55,2
	1200	55,1	73,9[1]	65,6	58,1	53,5 *61,8*[4]	58,1[2]

600	1000	58,2	79,5[1]	67,4	61,7	58,3	61,4[2]
	1200	61,6	95,5[1]	75,2	66,8	61,9	66,4[2]
Average		45,1		51,9	46,0	42,8	

[1] The system was not designed to calculate requirements for animals with this LW and DLWG

[2] Values marked with [1] were not included in the calculated average

[3] Values in brackets are NE requirement for maintenance

[4] Values in *italic* are NE requirements according to the practical feeding system in Holland based on VEVI-units (1000 VEVI = 6,9 MJ NE)

The Dutch system, which is based on protein and fat retention for NE_g, generally predicts the lowest energy requirements for bulls of dairy breeds. This is not due to a low maintenance requirement, since the Norwegian system estimates the lowest maintenance requirement. The French system estimates the highest maintenance requirement, which is 26% higher than the Norwegian system at 200 and 500 kg LW (Table 1). This is because the maintenance equation of dairy cows is used in the Norwegian system. At a LW of 200 kg the energy requirement for maintenance constitutes 46, 49, 63 and 63% of the total energy requirement in the Norwegian, Swedish, Dutch and French systems. The corresponding figures at 500 kg LW were: 60, 62, 69 and 72%, i.e. maintenance requirement constitutes a relatively bigger proportion of the total requirement as LW (age) increases. Note, that according to the practical feeding system used in Holland (CVB, 2000), the energy requirement is higher than what is estimated from the theoretical system. This actually results in a better agreement with especially the French system, but also the Swedish/UK and Danish systems.

The Swedish/UK systems estimate the highest NE requirement at a given LW and DLWG for bulls of dairy breeds (Table 1). This has also been illustrated in comparison with other systems (Figure A). The reason for the higher energy requirement in the UK-system for bulls of dairy breeds could be due to the fact that the equation was derived from results obtained with cattle which were earlier maturing than the Black and White bulls used by Schultz et al. (1974), Schiemann et al. (1976) and Van Es (1978) (Figure A) (cited from Van Es, 1978).

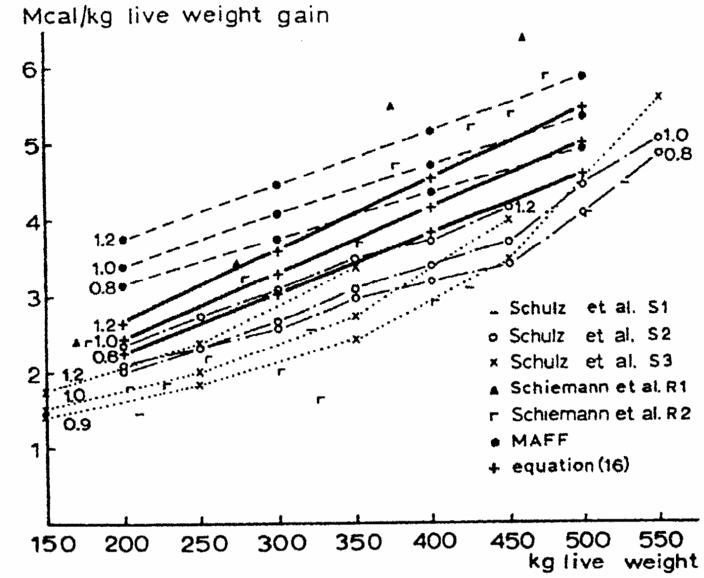


Figure A. Estimates of energy content per kg live weight gain at different live weights and live weight gains (0,8; 0,9; 1,0; 1,2) (from Van Es, 1978).

The equations used for calculating net energy (MJ/d) requirements for growth (NE_g) and maintenance (NE_m) to bulls of dairy breed were (LW is in kg & DLWG is in kg/day):

NO: NE_g: $(0,0029*LW+1000*0,0025*DLWG-0,952)*6,9$ *(Berg & Matre, 2001)*
NE_m: $(0,0424*LW^{0,75})*6,9$
(6,9 is a conversion factor from FE_m to MJ NE)

DK: NE_{mg}: $(2,17*\exp(0,00256*LW)*DLWG)*7,89$ *(Strudsholm et al., 1999)*
(7,89 is a conversion factor from FE to MJ NE)

SE/UK: NE_g: $(DLWG*(6,28+0,0188*LW))/(1-0,3*DLWG)$ *(MAFF, 1975)*
NE_m: $5,67+0,061*LW$

For calculations of ME_g: $ME_g = NE_g/k_g$ *(MAFF, 1975)*
where $k_g = 0,0435*$total amounts of MJ ME from diet/kg DMI
For calculations of ME_m: $ME_m=0,475*LW^{0,75}$ *(Thorbeck & Henckel, 1975)*

French: $(NE_m/k_m+NE_g/k_g)*k_{mg}$

NE_g: $(5,48*P+9,37*F)*4,184$ (MJ/day)
NE_m: $0,3682*LW^{0,75}$ (MJ/day)
k_m: $0,287*(ME/GE)+0,555$ (ME and GE are expressed in MJ/kg DM – *the relationship used in these calculations was 12,04/19,31 = 0,62*)
k_g: $0,35+0,25*(1-Ep)^2$
k_{mg}: $k_m* k_g*APL/(k_m+k_g*(APL-1))$ *(increases when energy for maintenance increases relatively to energy for growth due to the higher efficiency coefficient for maintenance compared to efficiency coefficient for growth)*
Ep: $4,184*5,48*(P/NE_g)$ *(expresses how large a proportion of the stored energy that comes from protein - the more protein the smaller k_g becomes. Biologically this is linked to a higher turnover in protein tissue compared to fat tissue)*
APL (animal production level): $(NE_m+NE_g)/NE_m$ *(APL is used to combine* k_m and k_g *into a common utilisation coefficient of ME to NE: k_{mg})*
P: protein retention (kg/d) = $0,1541*1,06*(EBWG-F)*FFM^{0,06}$
F: fat retention (kg/d) = $(((0,0189+0,362*\ln(EBW))*L)/EBW)*EBWG^{1,78}$

P, F retention calculated from equations developed by Robelin and Daenicke (1980), where FFM = Fat Free Mass (kg), EBWG: Empty Body Weight Gain (kg/d), EBW: Empty Body Weight (kg) and L: Lipid mass (kg)

Dutch: NE_g: $22,94*P+39,31*F$ *(Brandsma, 2006)*
NE_m: $0,33*LW^{0,75}$ *(Van Es, 1978)*

k_m and k_g are coefficients for utilisation of metabolizable energy for maintenance and growth, respectively, whereas k_{mg} is a combined coefficient. The utilisation of metabolizable energy increases with higher energy concentration in the diet due to relatively less heat production when more concentrates are included in the diet. The value of k_m normally lies between 0,65 and 0,80 while the value of k_g lies between 0,25 and 0,60 (Figure B).

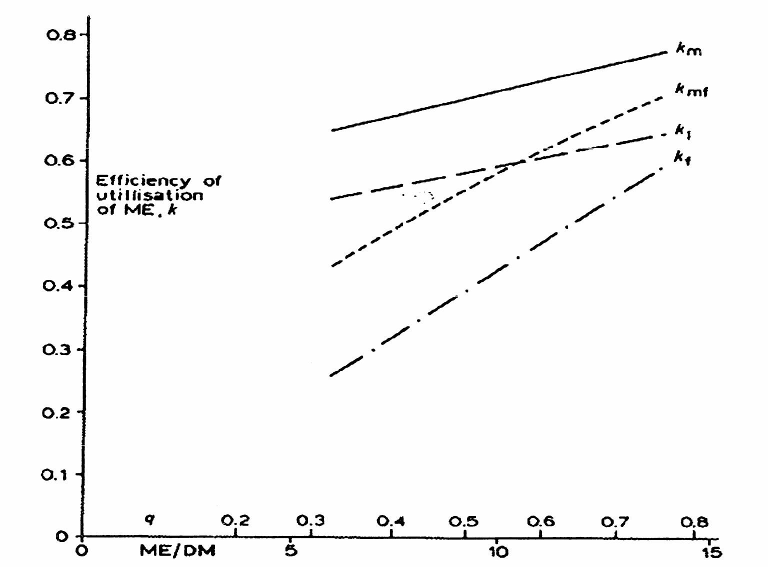


Figure B. Utilisation of metabolisable energy for maintenance (k_m), lactation (k_l), fattening (k_f) and maintenance+fattening as a function of ME concentration in DM (ME/DM) and the ratio between ME and GE (*q*) (from Van Es, 1975).

Table 2. A comparison of net energy requirements (MJ/d) calculated from different national systems to bulls of beef breeds (early maturing: AA, HRF) depending on live weight (LW) and average daily live weight gain (DLWG). Only the Swedish requirements are different from Table 1.

LW (kg)	DLWG (g/d)	NO (MJ/d)	DK (MJ/d)	SE (MJ/d)	French (MJ/d)	Dutch (MJ/d)	Average (MJ/d)
200	800	26,8	22,9	28,4	26,9	25,0	26,0
	1000	30,2	28,6	31,7	29,0	27,7 (29,0)[3]	29,4
	1200	33,7	34,3	35,6	31,3	30,9 (31,7)[3]	33,2
500	800	48,2	49,3	52,7	50,0	50,3	50,1
	1000	51,6	61,6	57,8	53,8	55,8 (53,1)[3]	56,1
	1200	55,1	73,9[1]	63,8	58,1	62,4 (58,7)[3]	59,9[2]
600	1000	58,2	79,5[1]	66,5	61,7	64,5	62,7[2]
	1200	61,6	95,5[1]	73,1	66,8	72,2	68,4[2]
Average		45,7		51,2	47,2	48,6	

[1] The system was not designed to calculate requirements for animals with this LW and DLWG

[2] Values marked with [1] was not included in the calculated average

[3] Values are NE requirements according to the practical feeding system in Holland based on VEVI-units (1000 VEVI = 6,9 MJ NE)

Only the Swedish system differentiates between dairy breeds and early maturing breeds (AA and HRF). I.e. Table 2 shows the same energy requirements as in Table 1, except for Sweden that uses the following equation, which is a modification of MAFF (1975):

SE: NE_g: ((DLWG*(6,28+0,0188*LW))/(1-0,3*DLWG)) *(MAFF, 1975)*
NE_m: 5,67+0,061*LW

$(NE_g + NE_m)*(1-0,21*(DLWG-0,8))$ *(Olsson & Lindell, 2002)*

The Swedish system consequently estimates a higher energy requirement for these beef breeds than the other systems for dairy breeds (except DK at 500 LW & 1000 DLWG) (Table 2). However, the difference in energy requirement between dairy- and early maturing breeds within the Swedish system is typically <1 MJ NE/day (Tables 1 & 2) and that might explain why the other systems do not differentiate.

Table 3. A comparison of net energy requirements (MJ/d) calculated from different national systems to bulls of beef breeds (late maturing: SIM, CHA and LIM)[1] depending on live weight (LW) and average daily live weight gain (DLWG).

LW (kg)	DLWG (g/d)	NO (MJ/d)	DK (MJ/d)	SE (MJ/d)	French (MJ/d)	Dutch[2] (MJ/d)	Average (MJ/d)
200	800	24,7	21,1	28,4	26,8	23,7	24,9
	1000	28,7	26,3	30,9	28,9	25,3 (28,3)	28,0
	1200	32,7	31,6	33,6	31,1	26,8 (31,1)	31,2
	1400	36,7	36,8	36,8	33,6	31,4 (34,2)	35,1
350	800	32,1	29,1	40,6	39,1	35,3	35,2
	1600	48,1	58,1	55,4	50,3	47,0 (50,0)	51,8
	1800	55,2	75,5	77,3	56,5	56,0	64,1
500	800	42,0	40,1	52,7	48,7	43,1	45,3
	1000	46,0	50,2	56,1	51,8	45,1 (49,3)	49,8
	1200	50,0	60,2	60,1	55,1	47,2 (53,5)	54,5
	1400	54,0	70,2	64,7	58,7	49,2 (58,0)	59,4
	1800	62,0	90,3	77,0	66,6	53,3	69,8
600	1000	54,1	62,2	64,5	58,5	50,9	58,0
	1200	58,1	74,6	68,9	62,2	53,1	63,4
750	1000	67,6	116,8	80,5	72,7	70,6 (69,7)	81,6
Average		46,1	56,2	55,2	49,4	43,9	

[1] In the Danish system LIM is categorised as an early maturing breed

[2] Values are NE requirements according to the practical feeding system in Holland based on VEVI-units (1000 VEVI = 6,9 MJ NE)

As it was the case for dairy breeds, the Dutch system also predicts the lowest energy requirements for bulls of beef breeds compared to the other systems. In order to get an impression of the differences between national systems a simple comparison was made between energy requirements for bulls of dairy and beef breeds. Bulls of dairy breeds (Table 1) have 1-9% (NO: 3%; DK: 9%; SE: 9%; French: 1%; Dutch: 4%) higher energy requirement depending on national system compared to late maturing bulls (Table 3) at 200 kg LW and a DLWG of 1200 g/day. At 500 kg LW and a DLWG of 1000 g/day, bulls of dairy breeds have a 23% higher energy requirement than late maturing bulls in the DK system. The corresponding figures for NO, SE, France and Holland are 12%, 4%, 4% and 12% respectively. Thus, the French system has an interestingly low difference in energy requirement between bulls of beef and dairy breeds.

The equations used for calculating net energy (MJ/d) requirements for growth (NE_g) and maintenance (NE_m) to bulls of beef breeds were (LW is in kg & DLWG is in kg/day):

NO: NE_g: $(-0,00555*LW+0,0000103*LW^2+1000*DLWG*0,002898-0,07)*6,9$

NE_m: $(0{,}0382*LW^{0,75})*6{,}9$ *(Berg & Matre, 2001)*
(6,9 is a conversion factor from FE_m to MJ NE)

DK: NE_{mg}: $(2{,}17*\exp(0{,}00215*LW)*DLWG)*7{,}89$ *(Strudsholm et al., 1999)*
(7,89 is a conversion factor from FE to MJ NE)

SE: NE_g: $((DLWG*(6{,}28+0{,}0188*LW))/(1-0{,}3*DLWG))$ *(MAFF, 1975)*
NE_m: $5{,}67+0{,}061*LW$
$(NE_g + NE_m)*(1-0{,}07*(DLWG-0{,}8))$ *(Olsson & Lindell, 2002)*

French: Same equations as described below Table 1.
Note: Because fat and protein retention is part of the French system, different energy requirements occurs for different young stock.

Dutch: Same equations as described below Table 1.

Table 4. A comparison of net energy requirements (MJ/d) calculated from different national systems to steers of large dairy breeds depending on live weight (LW) and average daily live weight gain (DLWG).

LW (kg)	DLWG (g/d)	NO (MJ/d)	DK (MJ/d)	SE (MJ/d)	French (MJ/d)	Dutch (MJ/d)	Average (MJ/d)
200	800	26,3	28,0	29,9	27,8		27,3
	1000	29,6	35,0	33,8	30,4		30,4
	1200	32,9	42,0	38,5	33,2		33,9
500	800	47,3	59,3	55,3	52,9		51,5
	1000	50,6	74,1	61,5	58,2		56,5
	1200	53,9	88,9	68,8	64,2		62,3
600	800	53,7	76,1	63,8	60,7		59,1
	1000	57,0	95,1	70,7	67,0		64,8
Average		43,9	62,3	52,8	49,3		

The equations used for calculating net energy (MJ/d) requirements for growth (NE_g) and maintenance (NE_m) to steers of large dairy breeds were (LW is in kg & DLWG is in kg/day):

NO: NE_g: $(-0{,}00555*LW+0{,}0000103*LW^2+1000*DLWG*0{,}002898-0{,}07)*6{,}9$
NE_m: $(0{,}0382*LW^{0,75})*6{,}9$ *(Berg & Matre, 2001)*
(6,9 is a conversion factor from FE_m to MJ NE)

DK: NE_{mg}: $((2{,}6904*\exp(0{,}0025*LW))*DLWG)*7{,}89$ *(Fisker & Bligaard, 2004)*
(7,89 is a conversion factor from FE to MJ NE)

SE: NE_g: $((DLWG*(6{,}28+0{,}0188*LW))/(1-0{,}3*DLWG))*1{,}05$ *(MAFF, 1975)*
NE_m: $(5{,}67+0{,}061*LW)*1{,}05$
Note: Same equation as for heifers. The 5% addition is a Swedish correction–factor.

French: Same equations as described below Table 1.
Note: Because fat and protein retention is part of the French system, different energy requirements occurs for different young stock.

Dutch: No equations or practical feeding recommendations available.

Table 5. A comparison of net energy requirements (MJ/d) calculated from different national systems to heifers of large dairy breeds depending on live weight (LW) and average daily live weight gain (DLWG).

LW (kg)	DLWG (g/d)	NO (MJ/d)	DK (MJ/d)	SE (MJ/d)	French (MJ/d)	Dutch[3] (MJ/d)	Average (MJ/d)
200	800	26,8	32,2	29,9	27,8	25,0	28,3
	1000	29,5	42,2	33,8	30,4	27,7	32,7
	1200	32,3	54,3[1]	38,5	33,2	30,9	33,7[2]
350	700	35,4	38,2	40,3	39,3	36,3 (40)	37,9
	900	38,1	50,6	45,0	43,0	40,1	43,4
500	500	41,7	34,9	47,7	46,3	43,5	42,8
	800	45,8	54,7	55,3	52,9	50,3	51,8
	1000	48,6	71,8[1]	61,5	58,2	55,8	56,0[2]
	1200	51,3	92,3[1]	68,8	64,2	62,4	61,7[2]
600	800	51,6	61,4[1]	63,8	60,7	58,1	58,6[2]
	1000	54,3	80,6[1]	70,7	67,0	64,5	64,1[2]
Average		41,4		50,5	47,5	45,0	

[1] The system was not designed to calculate requirements for animals with this LW and DLWG

[2] Values marked with [1] was not included in the calculated average

[2] Values in brackets are NE requirements according to the practical feeding system in Holland based on VEM-units (1000 VEM = 6,9 MJ NE)

Table 5 shows that the Norwegian system generally has the lowest energy requirements for heifers. The equations used for calculating net energy (MJ/d) requirements for growth (NE_g) and maintenance (NE_m) to heifers of large dairy breeds were (LW is in kg & DLWG is in kg/day):

NO: NE_g: (0,00177*LW+1000*0,002*DLWG-0,327)*6,9 *(Berg & Matre, 2001)*
NE_m: $(0,0424*LW^{0,75})*6,9$
(6,9 is a conversion factor from FE_m to MJ NE)

DK: NE_{mg}: (exp(ln((DLWG*1000+1738)/(3079-258*ln(LW)))/0,28))*7,89
(7,89 is a conversion factor from FE to MJ NE) *(Strudsholm et al., 1999)*

SE: NE_g: ((DLWG*(6,28+0,0188*LW))/(1-0,3*DLWG))*1,05 *(MAFF, 1975)*
NE_m: (5,67+0,061*LW)*1,05
Note: Same equation as for steers. The 5% addition is a Swedish correction –factor.

French: Same equations as described below Table 1.
Note: Because fat and protein retention is part of the French system, different energy requirements occurs for different young stock.

Dutch: NE_g: 0,004184*(500+6*LW)*(DLWG/(1-0,3*DLWG)) *(Van Es, 1978)*
NE_m: $0,33*LW^{0,75}$

Tables 1-5 show that there is a quite well agreement between the different national systems in terms of net energy requirements depending on live weight and daily gain. This suggests that the different systems predict the same protein and fat retention in the bulls although not all systems were designed that way. E.g. the Danish system is based on production trials, i.e. an empirical approach. However, this also implies that the Danish system is only useful within relatively narrow LW's and DLWG's, which is shown in Tables 1-5 by the values marked with ^{1}.

Conclusion

There is a quite well agreement between the different national systems in terms of net energy requirements depending on live weight and daily gain for bulls, heifers and steers. However, at high daily gains or high live weights, the Danish and Swedish systems have higher energy requirements than the other systems. The French system seems to have small differences in terms of energy requirement between animals of dairy and beef breeds at moderate daily gains. The Dutch system is more or less a copy of the French system, but the Dutch system does not include energy requirements for steers. The French system (and therefore also the Dutch system) seems to be the most robust one in terms of providing requirements closest to the average of different European systems. But, the French system is also the most complex one because it needs input on fat and protein retention and the dietary ME/GE ratio, i.e. the utilisation coefficient of ME to NE is unknown until the diet is defined and thereby also the NE supply from the diet. Nevertheless, this is the same approach used in the NorFor Plan dairy cow model. The Nordic systems only need information on LW and DLWG. It should be mentioned that originally the Swedish system was developed from the British, which was also based on fat and protein retention. We need to do some more testing of these energy systems in relation to production/experimental data, but it is concluded that the French system has the greatest potential for "NorFor Dyr i Vekst".

Energiværdi beregnet i NorFor Plan og i nationalt system

I dagens nationale systemer beregnes netto energi til laktation (FEm) i Norge, Foderenheder i Danmark (netto energi system) og omsættelig energi i Sverige. I det følgende afsnit sammenlignes energiværdien i en typisk national ration med energiværdien beregnet ud fra fordøjeligheder og energitilførsel i NorFor. Foderrationens indhold af omsættelig energi (ME) beregnes via følgende formel:

$$ME = \frac{18{,}0 \cdot td\_CPcorr + 37{,}7 \cdot td\_CFat + 14{,}5 \cdot \left(td\_CHO - \sum_i DMI_i \cdot Sugar_i \right) + 13{,}9 \cdot \sum_i DMI_i \cdot Sugar_i}{1000}$$

Hvor:

tdCPcorr = total tract digestibility of crude protein (corrected for urea and NH_3N in feed) (g/day)
tdCFat = total tract digestibility of crude fat (g/day)
tdCHO = total tract digestibility of carbohydrates (g/day)
DMI·sugar = dry matter intake of sugar (g/day)

Foderrationenes nettoenergiværdi (NEL) beregnes via følgende formel:

$$NEL = 0,6 \cdot \left(1 + 0,004 \cdot \left(\frac{ME \cdot 100}{\frac{24,1 \cdot \sum_i (DMI_i \cdot CPcorr)_i + 36,6 \cdot \sum_i (DMI_i \cdot CFat_i) + 18,5 \cdot \sum_i \left(DMI_i \cdot \left(OM_i - CPcorr_i - CFat_i - \frac{CP_i}{6,25} \cdot \frac{NH3N_i}{1000} \right)\right)}{1000}} - 57 \right)\right) \cdot ME$$

Hvor:

CPCorr = crude protein corrected for urea and NH_3N in feed (g/day)
CFat = crude fat (g/day)
OM = organic matter (g/day)
NH_3N = urea and NH_3N in feed (g/day)
ME = metabolizable energy (MJ/day)

Sammenligningen mellem en foderrations energiværdi i de nuværende landes systemer og i NorFor er foretaget ved at omregne NorFor-værdier til sammenlignelige størrelser i de nuværende energisystemer. Det er imidlertid vigtigt at understrege at energiværdien i NorFor Plan er udtrykt i nettoenergi til laktation og dermed ikke direkte tilpasset et energisystem til dyr i vekst. I Sverige bruges OE i det nuværende energisystem og da denne beregnes i NorFor Plan kan der laves en direkte sammenligning mellem de 2 systemer. For de Norske rationer er sammenligningen foretaget ved at NorFor's beregning af nettoenergi til laktation (NEL) er divideret med 6,9 (6,9 MJ NEL/FEm) hvorved man får FEm, som er det nuværende energisystem i Norge. I det Danske system beregnes FE ud fra følgende formel:

FE/kgTS = -0,369 + 0,0989*DE – 0,347*træstof (Weisbjerg & Hvelplund, 1993)

hvor DE er Digestible Energy (MJ/kg TS) og træstof (kg/kg TS).

DE kan udregnes ud fra NorFor Plan's beregninger af fordøjeligt fedt, protein og kulhydrat mens træstof-værdier er taget fra fodermiddeltabellen. Ved at bruge denne formel får man således en energiberegning i det nuværende Danske system, som man kan sammenligne med energiværdien af den pågældende ration udregnet efter landets nuværende system. Sådanne type beregninger er lavet både for kvier, tyre og stude i Norge, Sverige og Danmark. I Norge har Øystein Havrevoll fra Gilde, Cecilia Lindahl fra Taurus i Sverige og Thomas Ullner fra Dansk Kvæg i Danmark været behjælpelige med at fremskaffe type-rationer.

I det danske fodervurderingssystem til tyre og kvier kategoriseres PIE, LIM, AA og HRF samt malkeracer (DJ, DRH, DH, RD) som tidlig slagtemodne (højeste foderforbrug per kg tilvækst), Blonde karakteriseres som medio slagtemoden, mens CHA og SIM karakteriseres som sent slagtemodne (laveste foderforbrug per kg tilvækst). I det svenske system har de tunge kødracer CHA, SIM og LIM det laveste foderforbrug per kg tilvækst og malkeracerne det højeste foderforbrug per kg tilvækst, mens de lette kødracer (AA og HRF) har et foderforbrug mellem de tunge kødracer og malkeracerne. I Norge har man 2 kategorier hvor NRF, AA og HRF er tidlig slagtemodne og dermed har et højere foderforbrug per kg tilvækst end LIM, CHA og SIM som er sent slagtemodne. Der er således forskel på energitildelingen til ungdyr mellem de danske, svenske og norske systemer.

Geay & Robelin (1979) kategoriserede 3 genotyper: malkeracer er tidlig slagtemodne og CHA, LIM og Blonde er sent slagtemodne mens Saler, Normand og Montbeliard er midt i mellem. Robelin & Daenicke (1980) definerede 4 grupper af dyr: meget tidlig slagtemodne (AA, HRF), tidlig slagtemodne (Friesian type), sent slagtemodne (CHA, LIM) og "dual purpose breeds" (SIM, Saler).

Man kunne forvente, at den nationale energi-norm og den mængde energi, som tilføres via foderrationen (beregnet i nationalt energisystem) skulle stemme overens. Men der ses mindre afvigelser mellem den nationale norm og hvad som tilføres, fordi der kan være tale om praktiske mål. For eksempel kan der være anvendt 0,5 kg byg selvom beregningen ud fra normen siger at der skal anvendes 0,43 kg.

Kvier

Den norske ration til kvier består af grovfoder om vinteren og afgræsning om sommeren samt ca. 1 kg kraftfoder dagligt. Den daglige tilvækst (DTV) var planlagt til 600g for drægtige kvier og 700g for ikke drægtige. De svenske rationer indeholder typisk 1-1,5 kg kraftfoder (incl. korn) ved en DTV på 650g og 0,5-1 kg kraftfoder ved en DTV på 550g. Den danske ration til kvier (ikke drægtige) består udelukkende af grovfoder i form af majs- og kløvergræsensilage og DTV var planlagt til 700g.

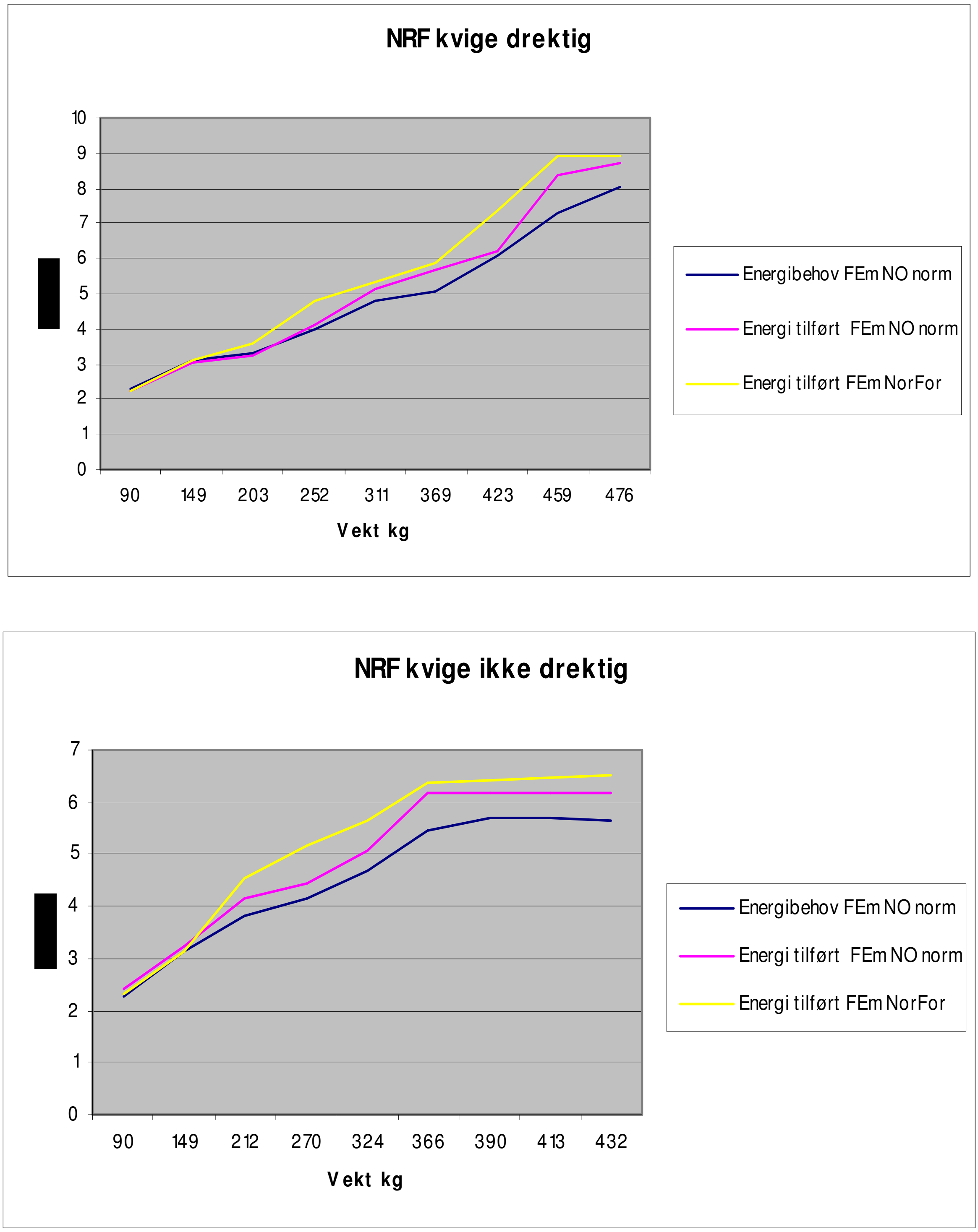
Som det fremgår af Figur 1-4 er energiværdien højere i NorFor end i det nationale system for norske og danske rationer og af en størrelsesorden på typisk 0,5 FE, hvilket svarer til 3,5-4,0 MJ NE (afhængig af om omregningsfaktoren er 6,9 (NO) eller 7,9 (DK). De svenske rationer derimod vurderes omvendt, således at NorFor vurderer energiindholdet i en ration ca. 5 MJ OE (ca. 3 MJ NE) lavere end det er tilfældet i Sverige's nuværende system til ungdyr.

Tyre

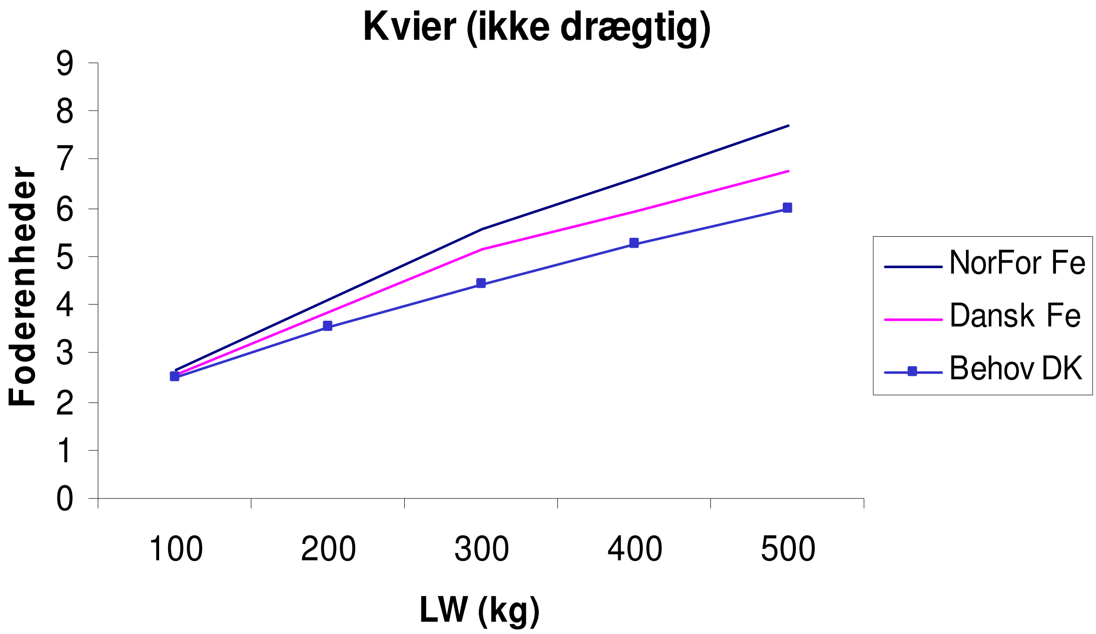
Som det fremgår af nedenstående figurer (Figur 5-8) undervurderer det norske system energitilførslen sammenlignet med NorFor Plan for tyre, især ved kropsvægte >400 kg. Det svenske og danske system overvurderer energitilførslen sammenlignet med NorFor. For de danske rationers vedkommende skyldes dette sandsynligvis at rationerne er meget stivelsesrige.

Stude

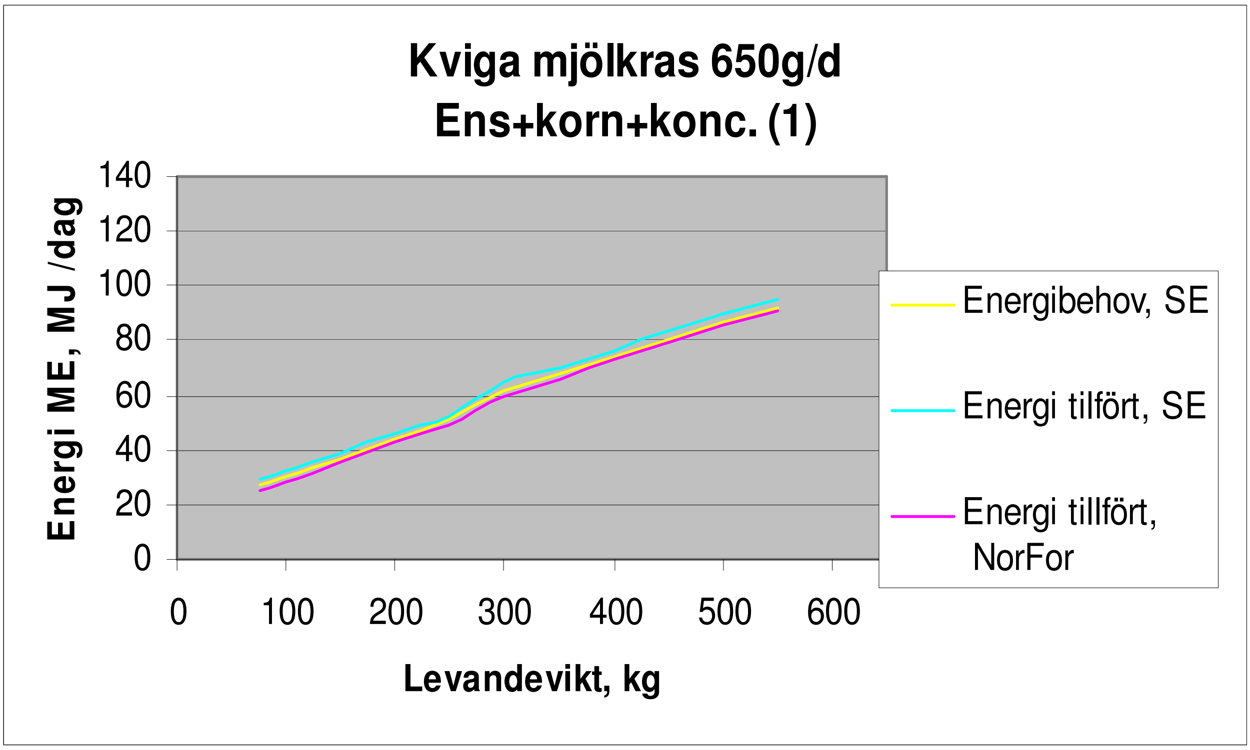
Som det var tilfældet for kvierne, ses det, at for studene opvurderes de norske og danske rationer i energiindhold i NorFor Plan sammenlignet med de nationale systemer, mens det omvendte er tilfældet for de svenske rationer (Figur 9-11).

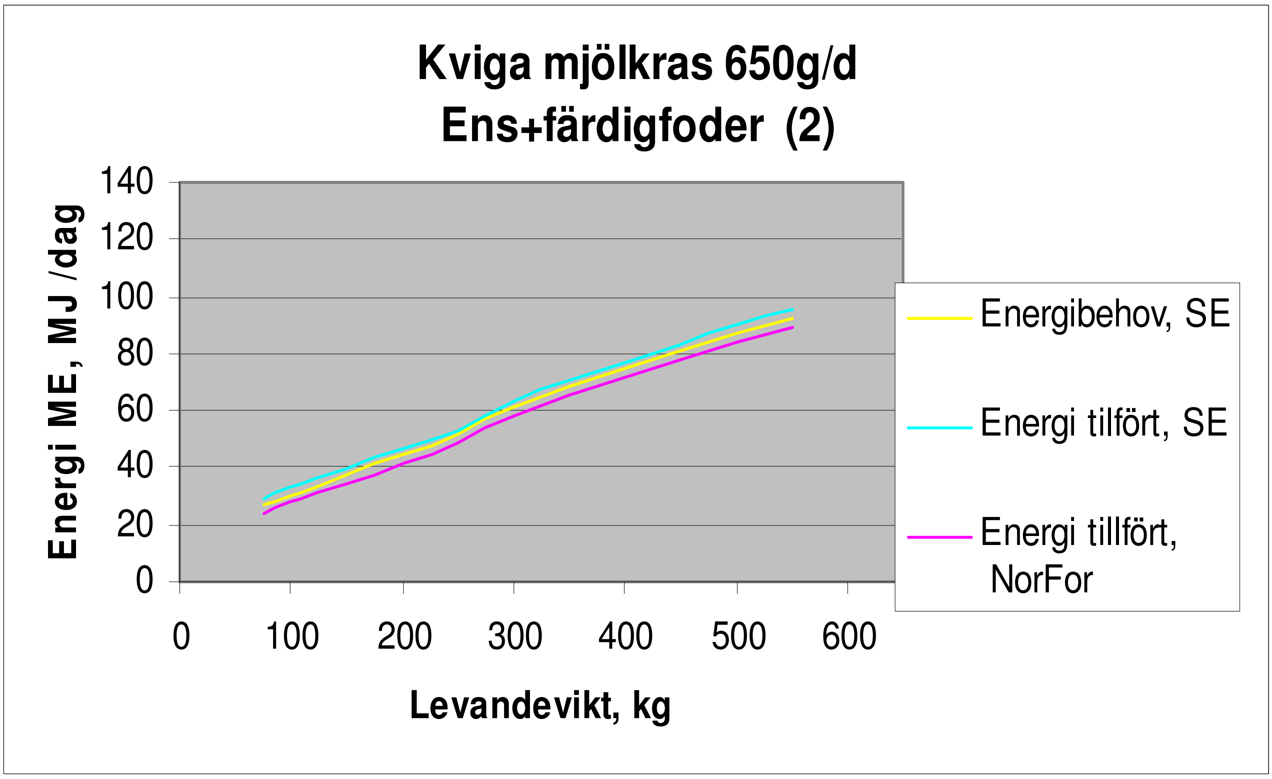


Figur 1. Energitilførsel beregnet efter Norge's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til drægtige/ikke drægtige NRF kvier. Rationen består primært af grovfoder og ca. 1 kg kraftfoder.

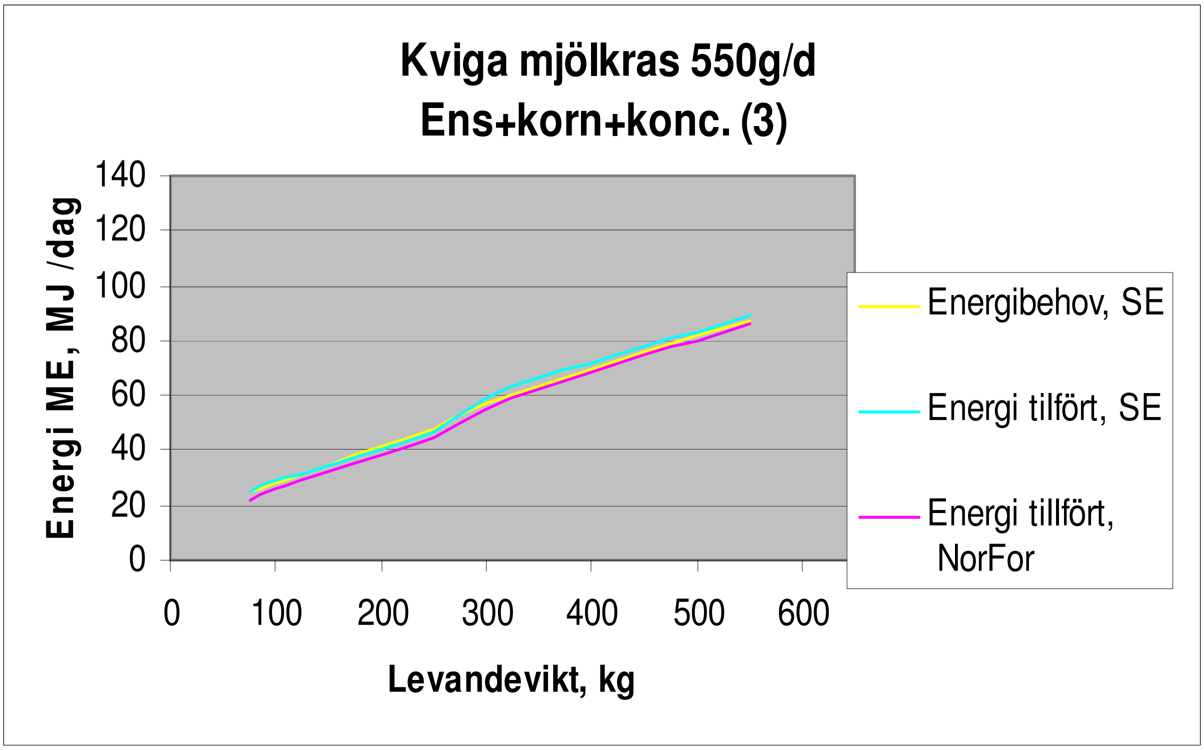


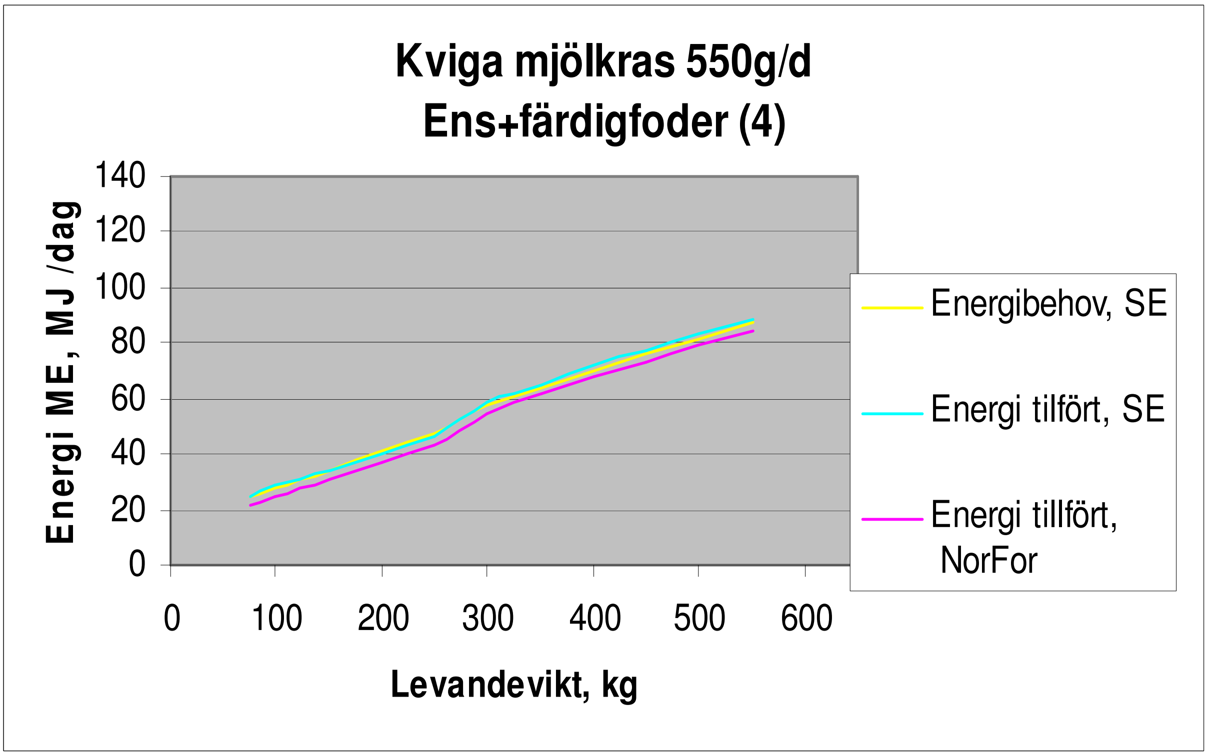
Figur 2. Energitilførsel beregnet efter DK's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til ikke drægtige kvier (700g daglig tilvækst) af malkeracer (DH, RD) og kødkvægsracer (AA, HRF, LIM, PIE). Rationen består af majs- og kløvergræsensilage.



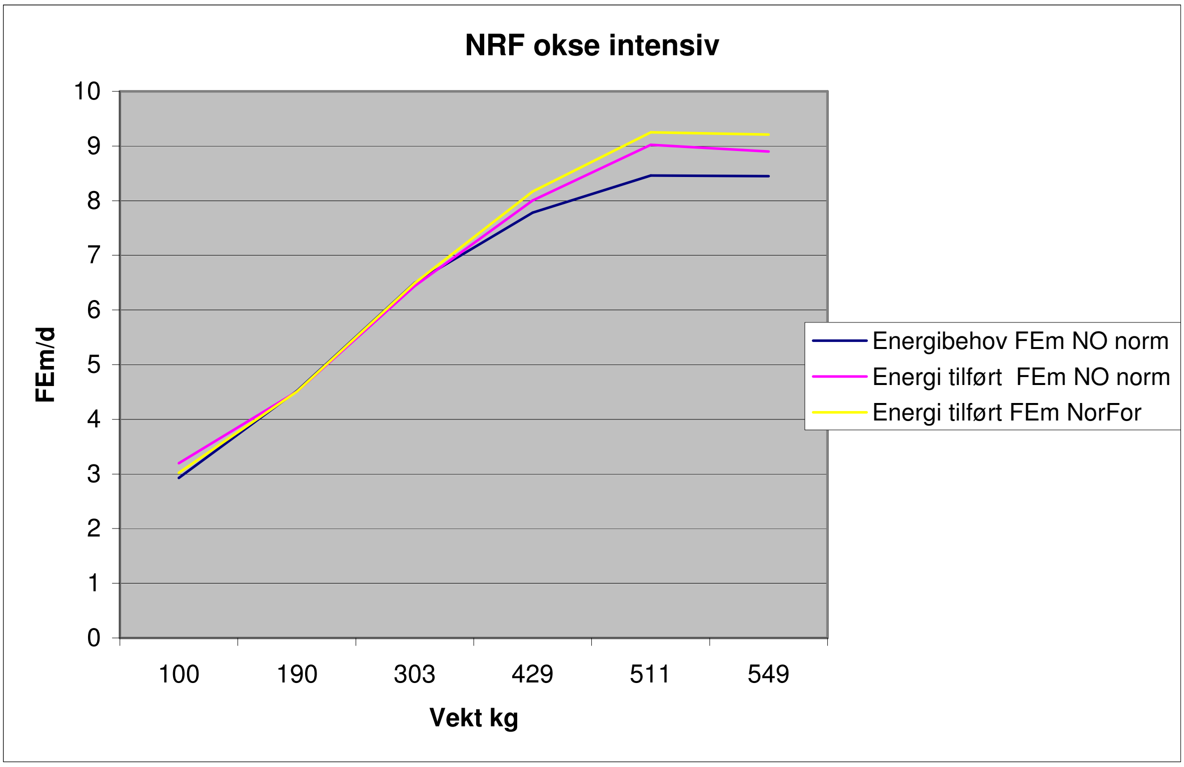


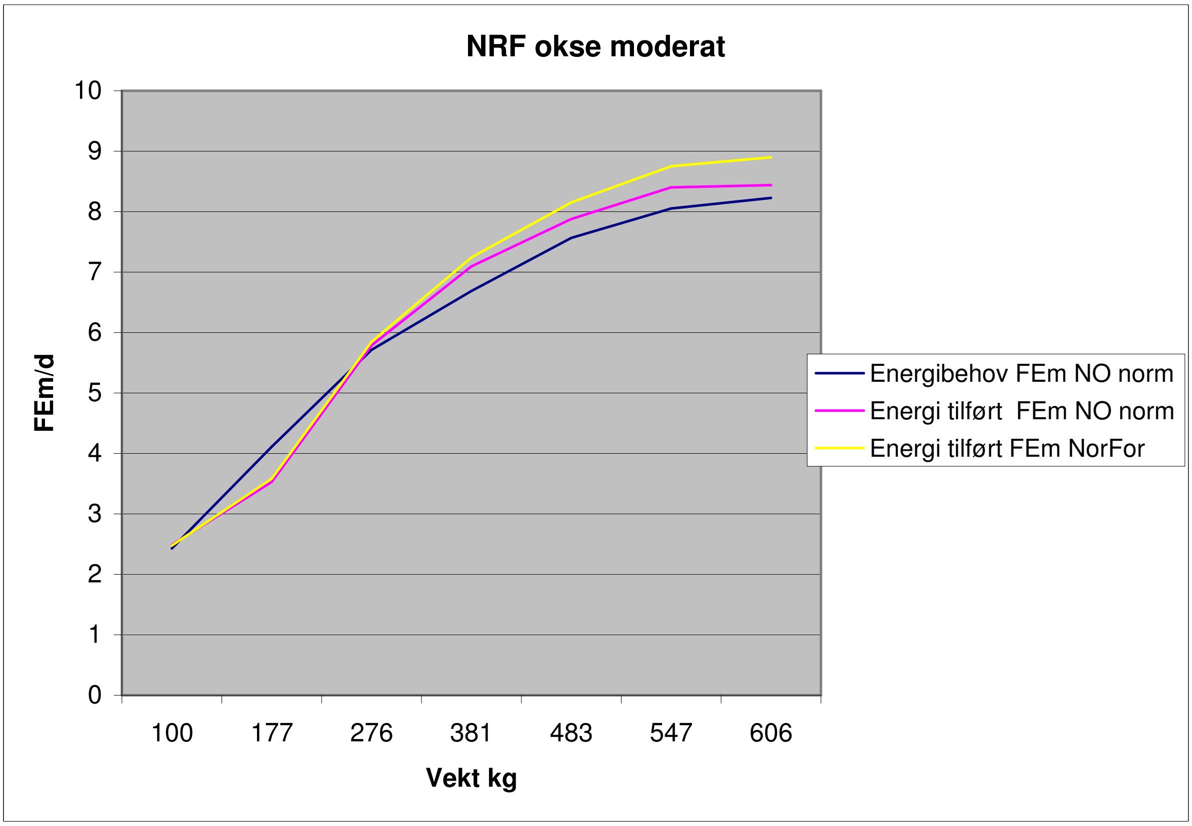
Figur 3. Energitilførsel beregnet efter Sverige's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til kvier af malkeracer (SLB, SRB). Rationen består af ensilage og 1-1,5 kg kraftfoder (incl. korn). ME: omsættelig energi



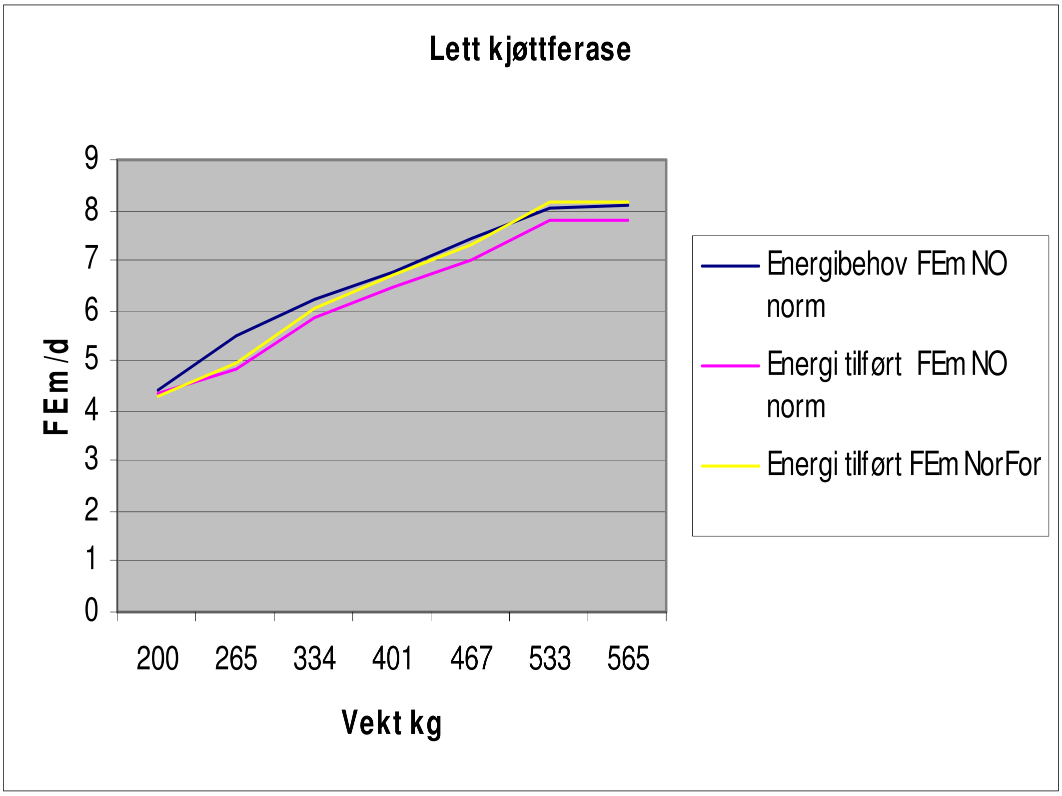


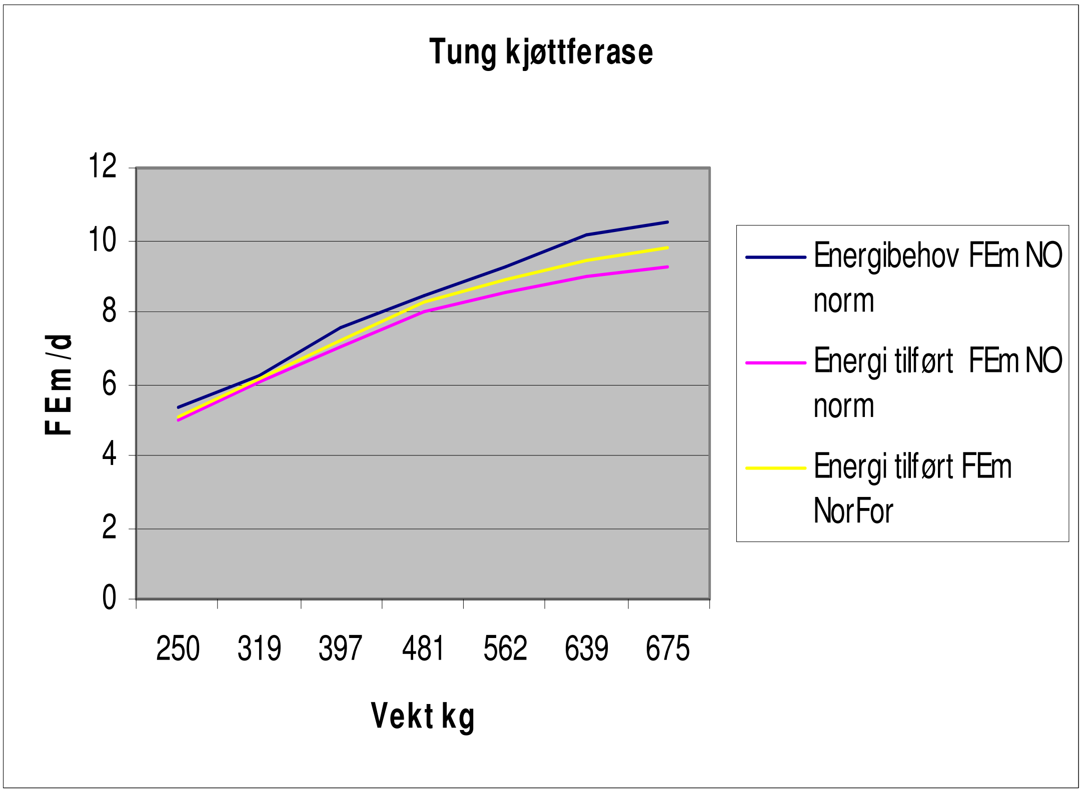
Figur 4. Energitilførsel beregnet efter Sverige's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til kvier af malkeracer (SLB, SRB). Rationen består af ensilage og 0,5-1,0 kg kraftfoder (incl. korn). ME: omsættelig energi



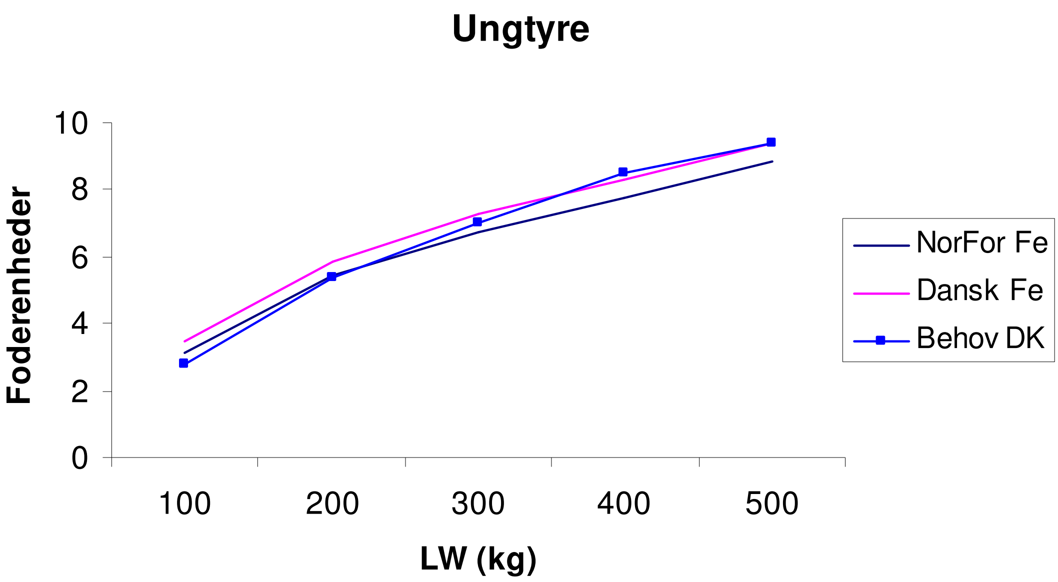


Figur 5. Energitilførsel beregnet efter Norge's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til NRF-okser. Rationen består af ca. halv kraftfoder og halv ensilage på tørstofbasis op til 350 kg og derefter overvejende grovfoder.

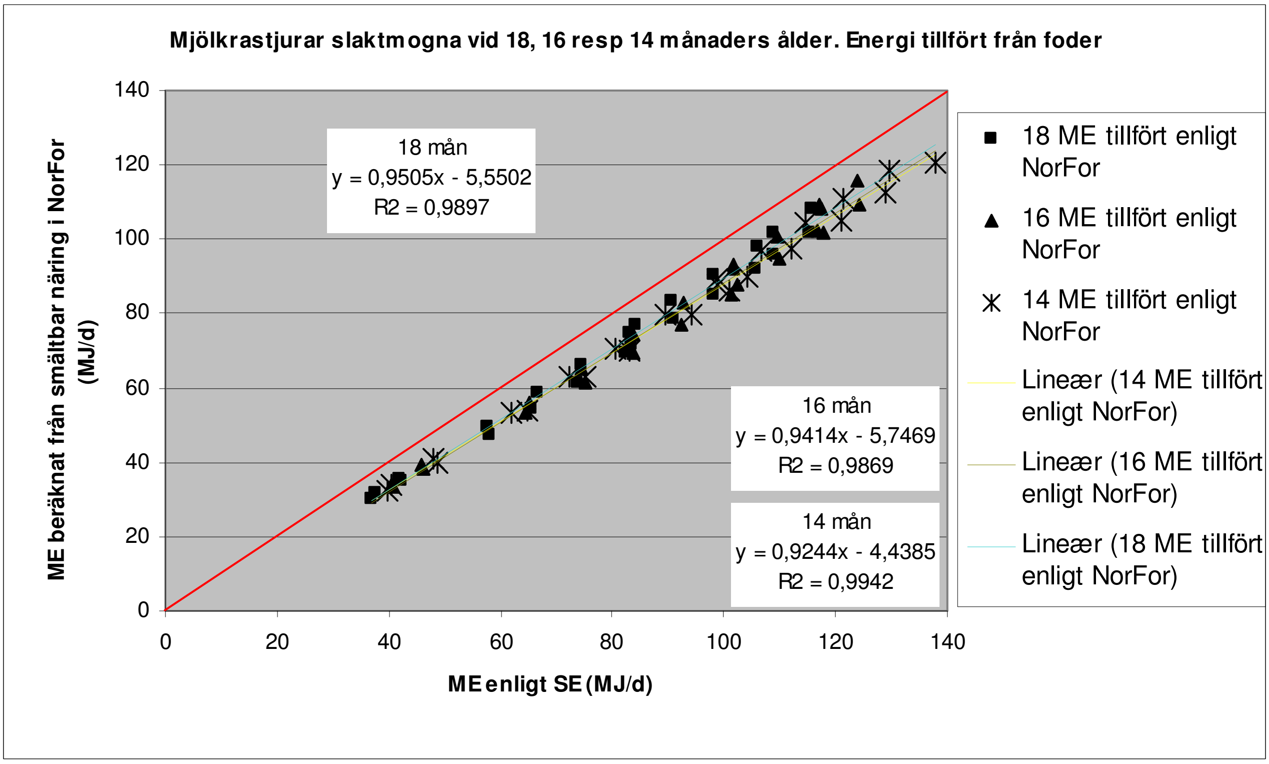




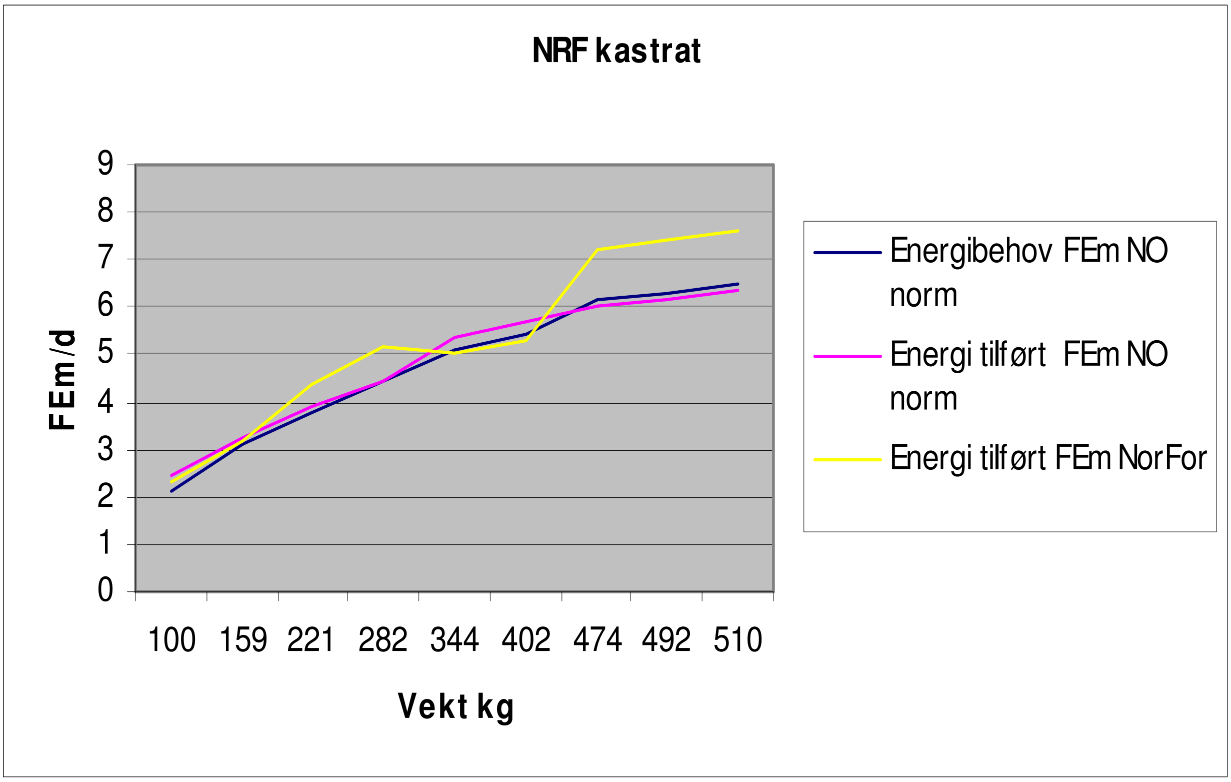
Figur 6. Energitilførsel beregnet efter Norge's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til tunge kjøttferacer (CHA & LIM). Rationerne består af ca. halv kraftfoder og halv ensilage på tørstofbasis gennem hele vækstforløbet.



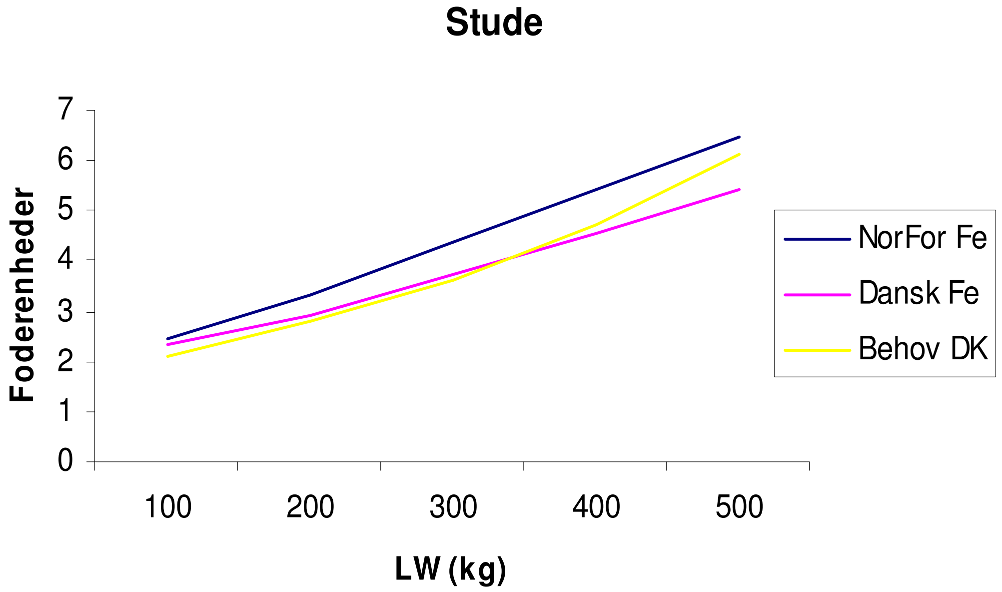
Figur 7. Energitilførsel beregnet efter DK's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til ungtyre af malkeracer og kødkvægsracer. Rationen består primært af byg samt lidt sojaskrå (<1 kg) og halm (<1 kg). Rationen er planlagt til en daglig tilvækst på 1,0, 1,5, 1,5, 1,4 og 1,2 kg ved henholdsvis 100, 200, 300, 400 og 500 g/dag.



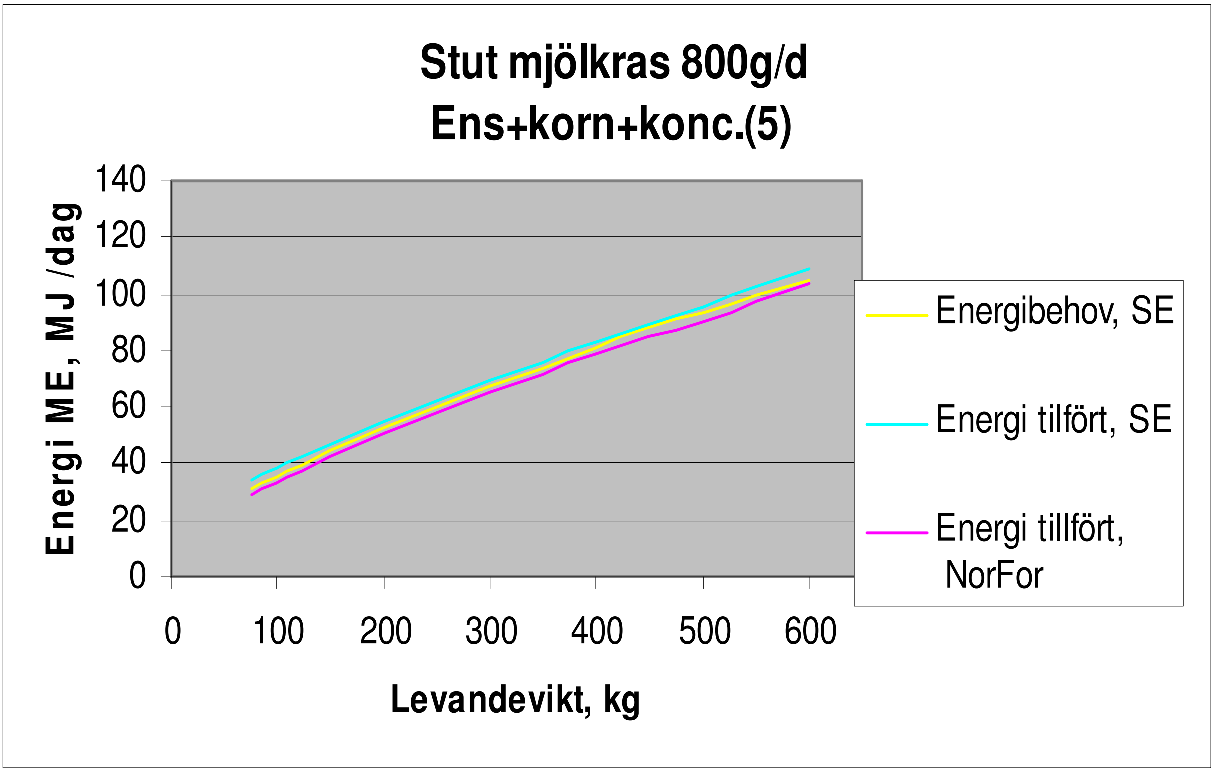
Figur 8. Energitilførsel beregnet efter Sverige's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til ungtyre af malkeracer. Det svenske system overvurderer energiindholdet i en ration sammenlignet med Norfor.

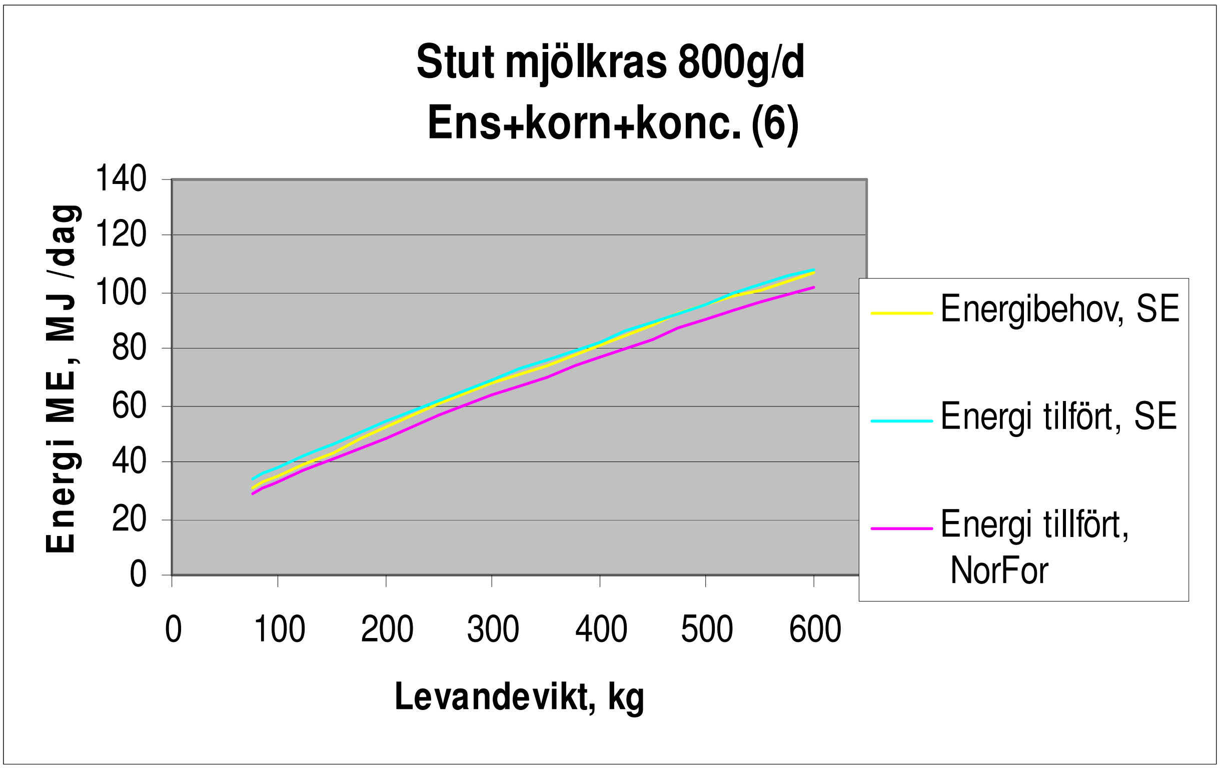


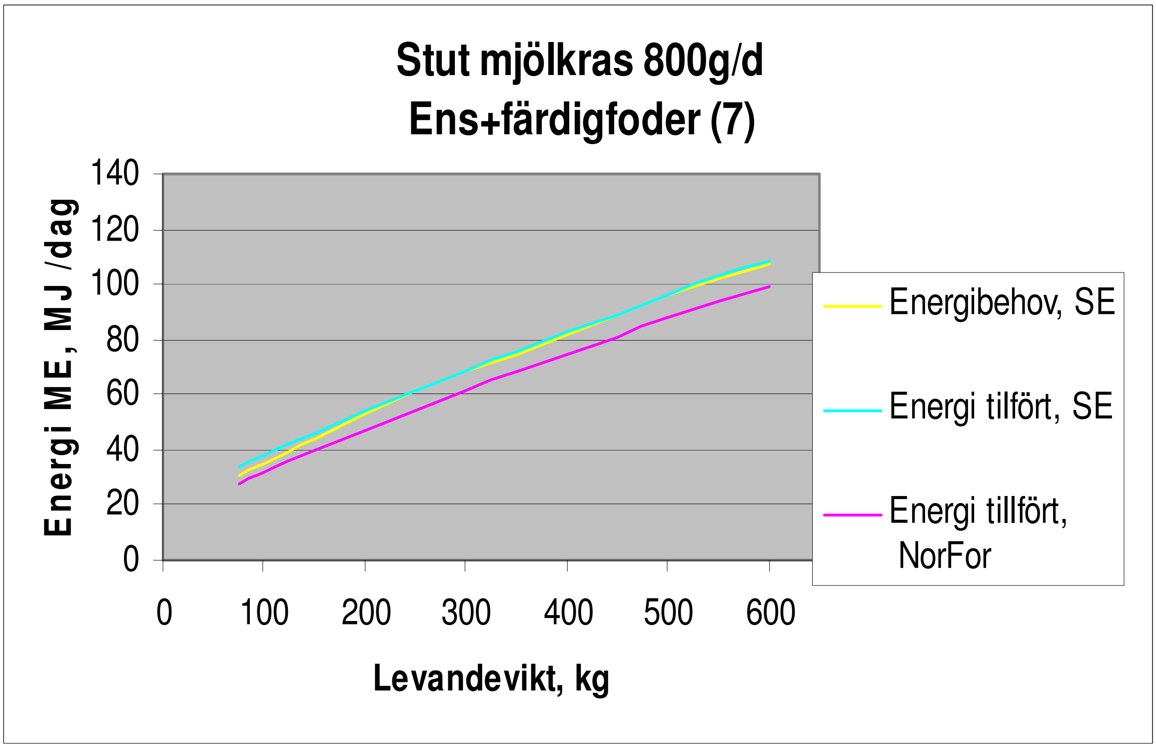
Figur 9. Energitilførsel beregnet efter Norge's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til NRF-stude ved 700g daglig tilvækst. Rationerne består næsten udelukkende af grovfoder. Grunden til at FEm NorFor (gul kurve) reduceres ved 344 og 402 kg skyldes ca. 4 kg TS halm, som vurderes forskelligt i det norske system og NorFor.



Figur 10. Energitilførsel beregnet efter DK's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til stude af malkeracer (DH, RD) med en daglig tilvækst på 700g. Rationen består udelukkende af kløvergræsensilage samt 1 kg byg ved 100 kg kropsvægt.


Stut mjölkras 800g/d
Ens+korn+konc.(5)
Energi ME, MJ /dag
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
Levandevikt, kg
Energibehov, SE
Energi tilfört, SE
Energi tillfört, NorFor


Stut mjölkras 800g/d
Ens+korn+konc. (6)
Energi ME, MJ /dag
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
Levandevikt, kg
Energibehov, SE
Energi tilfört, SE
Energi tillfört, NorFor



Figur 11. Energitilførsel beregnet efter Sverige's nuværende fodervurderingssystem og på basis af NorFor Plan's fordøjeligheder til stude af malkeracer (SLB, SRB). Rationerne indeholder typisk 1-2 kg kraftfoder (incl. korn). Det ses, at det svenske system overvurderer rationens energiindhold sammenlignet med NorFor.

Vurdering af fordøjelsesparametre i NorFor Plan for ungdyr rationer

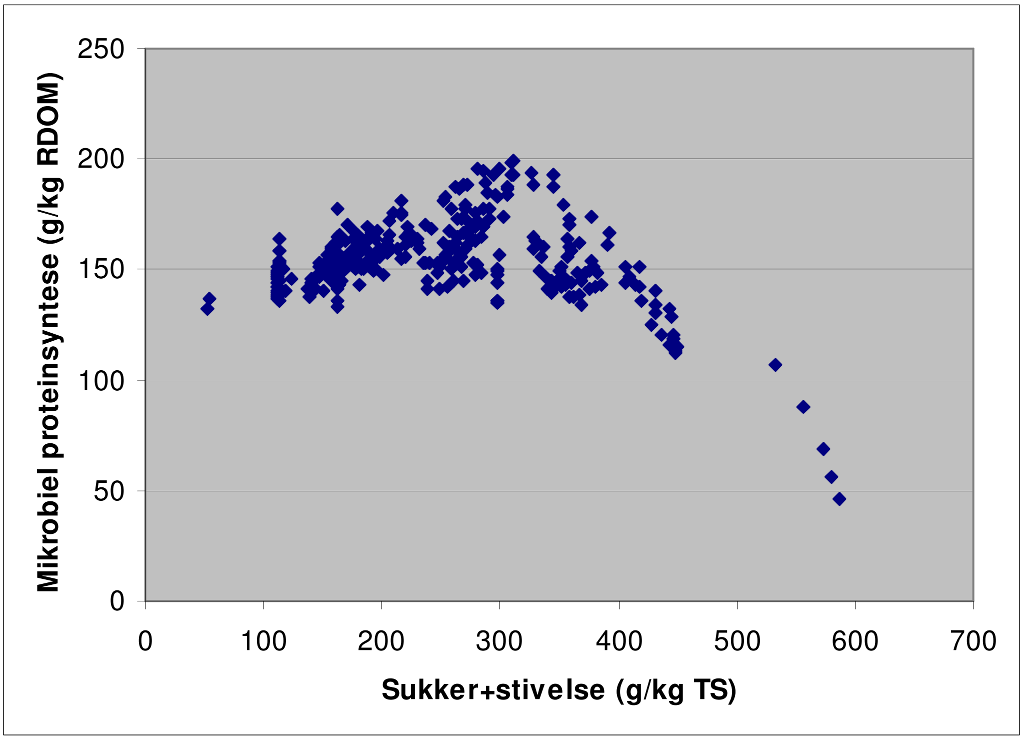
Formålet med dette afsnit er at vurdere NorFor's fordøjelsesmodel i relation til ungdyr-rationerne.

Effektiviteten i den mikrobielle proteinsyntese

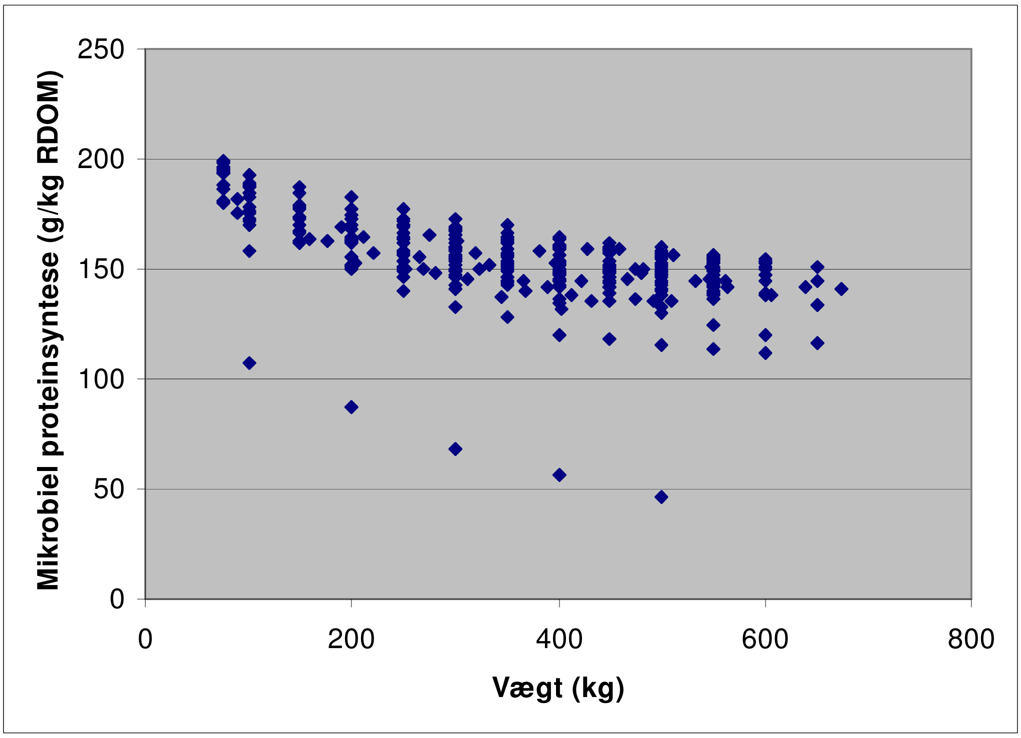
Det fremgår af Figur 12, at effektiviteten i den mikrobielle proteinsyntese er højest omkring 300 g sukker+stivelse i rationen, mens denne falder kraftigt når man er >400 g. På baggrund af ungdyr-rationerne er det vurderet at effektiviteten i den mikrobielle proteinsyntese bliver for lav når sukker+stivelse i rationen er højere end 500 g/kg TS. Ligningen for beregning av effektiviteten i den mikrobielle proteinsyntese i NorFor Plan er parameteriseret ud fra in vivo forsøg gennemført med malkekøer. I disse forsøg havde ingen af forsøgsbehandlingene så højt indhold af sukker + stivelse som 500 g/kg TS. Det betyder, at ungdyrrationer, som har et sukker + stivelse indhold >500 g/kg TS, er udenfor parameteriseringsgrundlaget.

Fordøjeligheden af organisk stof og NDF

NorFor beregner en fordøjelighed af NDF på ca. 20 %, når tyre fodres intensivt med korn, sojaskrå og halm (Figur 14). Dette er rationer som inneholder >80 % kraftfoder og er derfor rationer, som ligger udenfor parameteriseringsgrundlaget for NorFor Plan. Det er derfor nødvendigt med et litteraturstudie for at klarlægge hvad, som er det rigtige niveau for NDF- og OM-fordøjelighed ved denne type foderrationer, sådan at man kan tilpasse NorFor Plan.

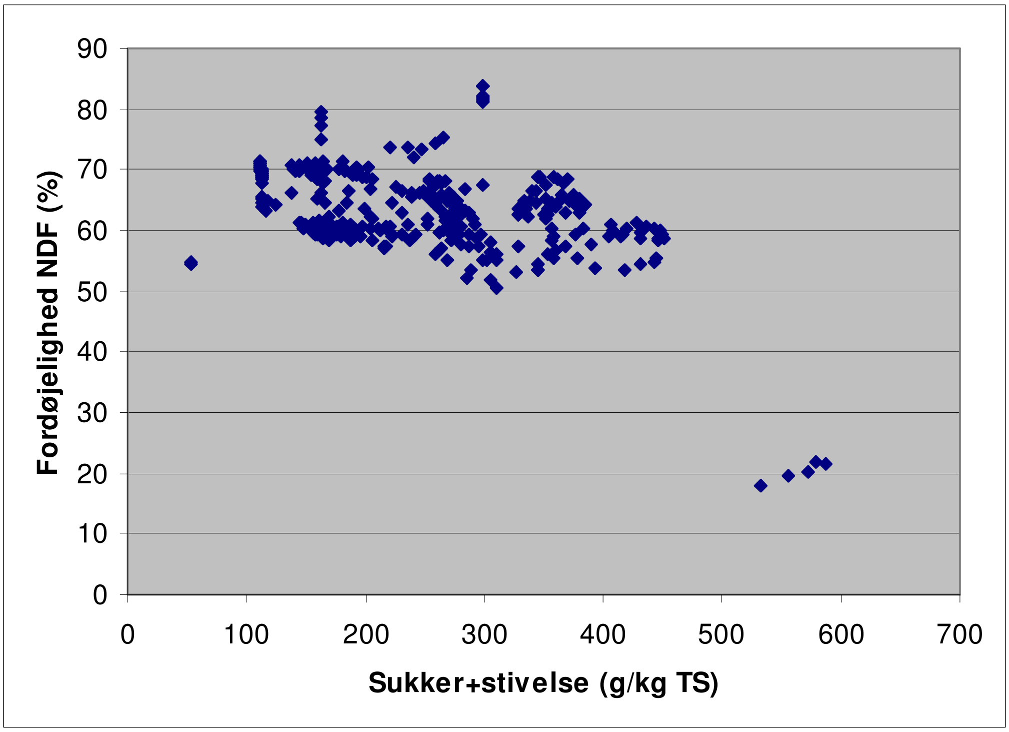


Figur 12. Sammenhæng mellem foderrationens indhold af sukker+stivelse og effektiviteten i den mikrobielle proteinsyntese i vommen udtrykt i g/kg rumen digested organic matter (RDOM). Data fra alle rationer i alle 3 lande. Det er tyrene på den danske ration, der har den laveste effektivitet i den mikrobielle proteinsyntese (48-107 g/kg RDOM).

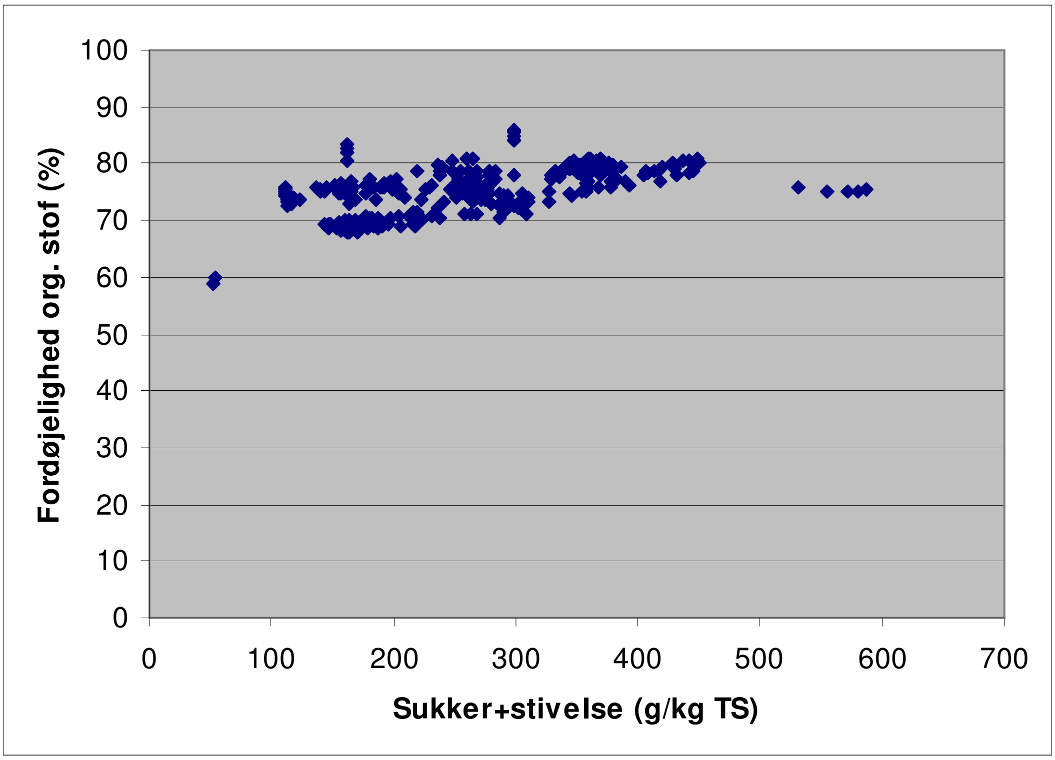


Figur 13. Sammenhæng mellem vægten af dyret (kvier, stude og tyre) og effektiviteten i den mikrobielle proteinsyntese i vommen. Data fra alle rationer i alle 3 lande. Det er tyrene på den

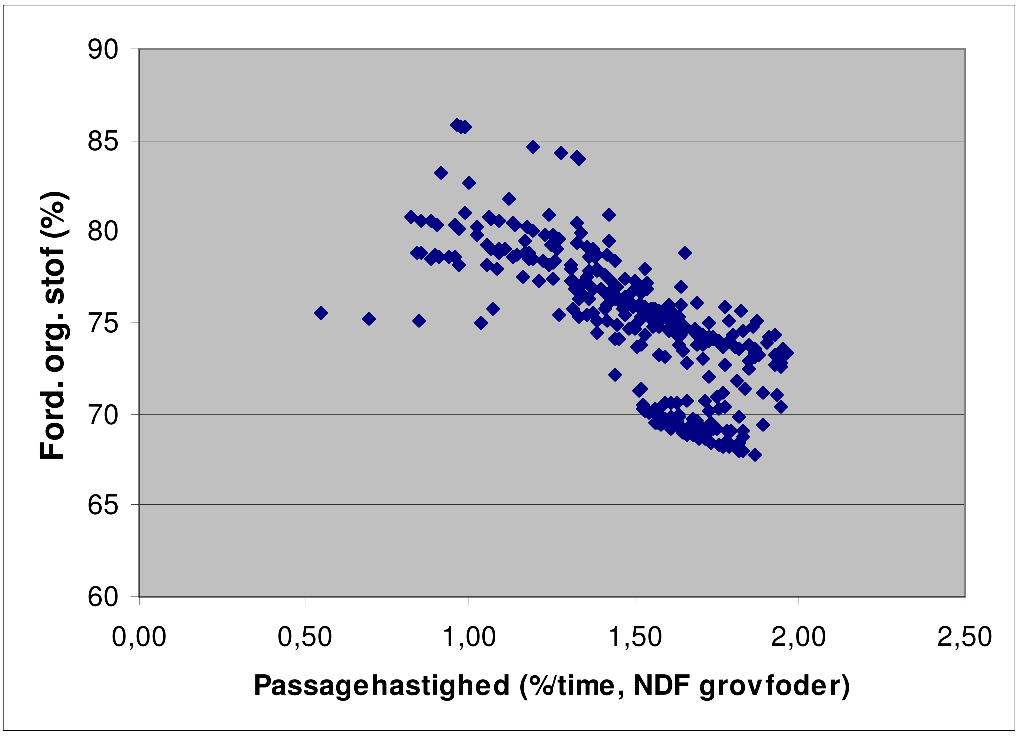
danske ration, der har den laveste effektivitet i den mikrobielle proteinsyntese (48-104 g/kg RDOM). Effektiviteten i den mikrobielle proteinsyntese påvirkes af dyrets kropsvægt således at den øges ved lavere kropsvægte.



Figur 14. Sammenhæng mellem foderrationens indhold af sukker+stivelse og total fordøjeligheden af NDF. Data fra alle rationer i alle 3 lande. Det er tyrene på den danske ration, der har den laveste fordøjelighed af NDF på ca. 20%.



Figur 15. Sammenhæng mellem foderrationens indhold af sukker+stivelse og total fordøjeligheden af organisk stof. Data fra alle rationer i alle 3 lande. Det er kastrater på den norske ration ved 350-400 kg, som fodres med ca. 4 kg TS halm, der har den laveste fordøjelighed af organisk stof på ca. 60%. De højeste fordøjeligheder af organisk stof (>80%) er opnået ved kastrater og kvier, som er på græs (beite).



Figur 16. Sammenhæng mellem passagehastigheden af NDF i grovfoder og fordøjeligheden af organisk stof. Data fra alle rationer i alle 3 lande. Det er tyrene på den danske ration, der har en fordøjelighed på ca. 75% på trods af en relativ lav passagehastighed på 0,5-1,0%. Det indikerer at nedbrydningshastigheden af NDF er reduceret pga. vombelastning. De højeste fordøjeligheder af organisk stof (>80%) er opnået ved kastrater og kvier, som er på græs (beite). Den generelle trend er at fordøjeligheden af organisk stof falder med stigende passagehastighed af NDF i grovfoder.

Konklusion

- Generelt opfører fordøjelsesmodellen i NorFor Plan sig fornuftigt i relation til de rationer der typisk fodres med i Norge, Sverige og Danmark til kvier, stude og tyre.
- Desto højere eller lavere kraftfoder/grovfoder forholdet er i en ration desto større afvigelse er der mellem NorFor Plan og de nationale systemer. Dette er forventeligt, eftersom NorFor reducerer fordøjeligheden af NDF ved højere niveauer af stivelse+sukker.
- Generelt overvurderer NorFor energiindholdet i norske rationer og til dels danske rationer, mens de svenske rationer konsekvent nedvurderes sammenlignet med dagens systemer. Det skal bemærkes at de danske rationer enten er meget grovfoderrige eller meget kraftfoderrige, hvilket giver en vis konfundering mellem system og ration.
- Foderrationerne og beregningerne har givet anledning til at ligningen for effektiviteten i den mikrobielle proteinsyntese ændres fordi det vurderedes at syntesen var for lav ved høje mængder stivelse+sukker i rationen.
- Det er nødvendigt med et litteraturstudie for at klarlægge om de beregnede fordøjeligheder på ca. 20% for NDF-fraktionen er passende ved høje mængder sukker+stivelse.

Tilpasninger af Fordøjelsesmodellen til "Dyr i vekst"

På baggrund af beregningerne og figurerne blev det på en workshop i august 2006 i Danmark bestemt at revidere ligningen for beregning af effektiviteten i den mikrobielle proteinsyntese. Desuden blev det besluttet at lave et review omkring stivelsesindholdet/energikoncentrationen i en ration og dets betydning for fordøjeligheden af NDF og organisk stof, bl.a. for at klarlægge om de beregnede fordøjeligheder på ca. 20% for NDF-fraktionen ved meget kraftfoderrige rationer er passende.

Mikrobiel proteinsyntese

Den originale og reviderede ligning for beregning af effektiviteten i den mikrobielle proteinsyntese er vist herunder. Konsekvensen af den nye ligning for effektiviteten i den mikrobielle proteinsyntese er vist i figur 17 og 18.

Original ligning:

$$r\_emCP = \ln\left(\frac{1000 \cdot \sum_i DMI_i}{BW\_cur}\right) \cdot 55{,}6 + 0{,}4166 \cdot \frac{\sum_i DMI_i \cdot ST_i + \sum_i DMI_i \cdot \mathrm{Re}\,stCHOcorr_i}{\sum_i DMI_i} -$$

$$0{,}0008868 \cdot \left(\frac{\sum_i DMI_i \cdot ST_i + \sum_i DMI_i \cdot \mathrm{Re}\,stCHOcorr_i}{\sum_i DMI_i}\right)^2 - 54{,}56$$

for the i=1...n'th feedstuff

Forkortelser:

r_emCP = effektiviteten i den mikrobielle proteinsyntese i vommen

BW_cur = aktuel kropsvægt; DMI = tørstofoptagelse; ST = stivelse

RestCHOcorr = rest kulhydrater ("corr" betyder korrigeret for urea og ammoniak-N i foder)

Ny ligning:

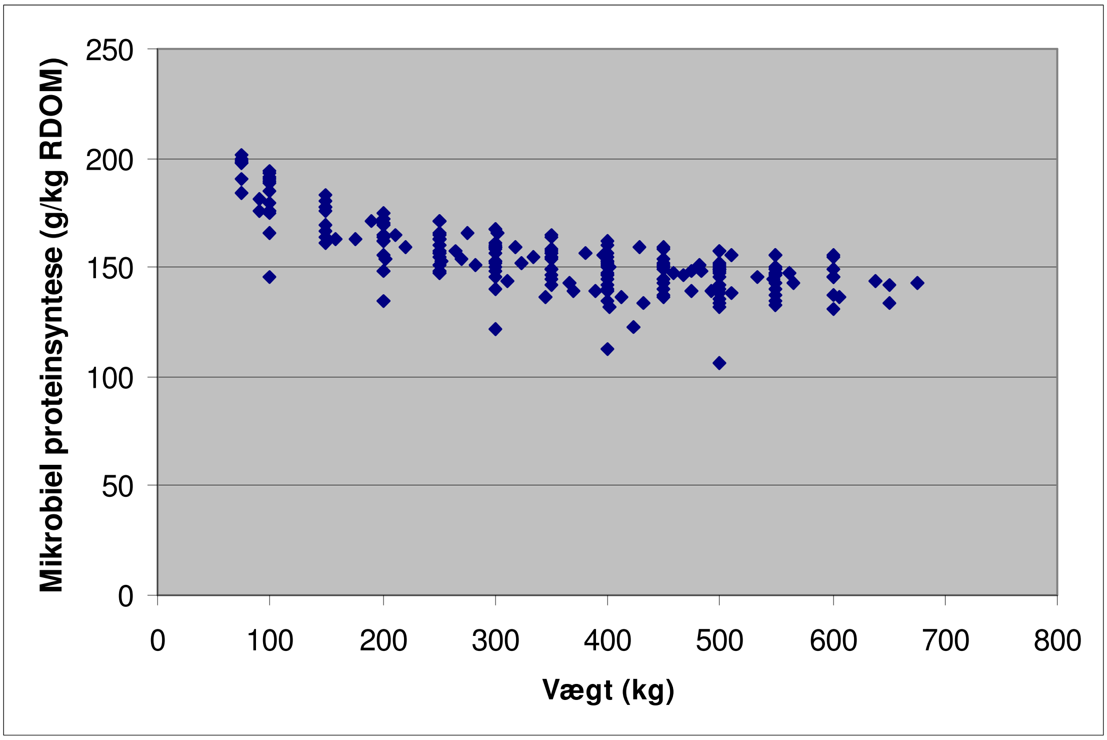
r_emCP = ln(1000*DMI/BW_cur)*55,6 +
(3,17+0,248*X-0,0004523*X^2)/(1-0,001879*X+0,000004248*X^2) - 50,8

X = indhold af RestCHOcorr+Stivelse i en ration (g/kg TS) udregnet via formlen:

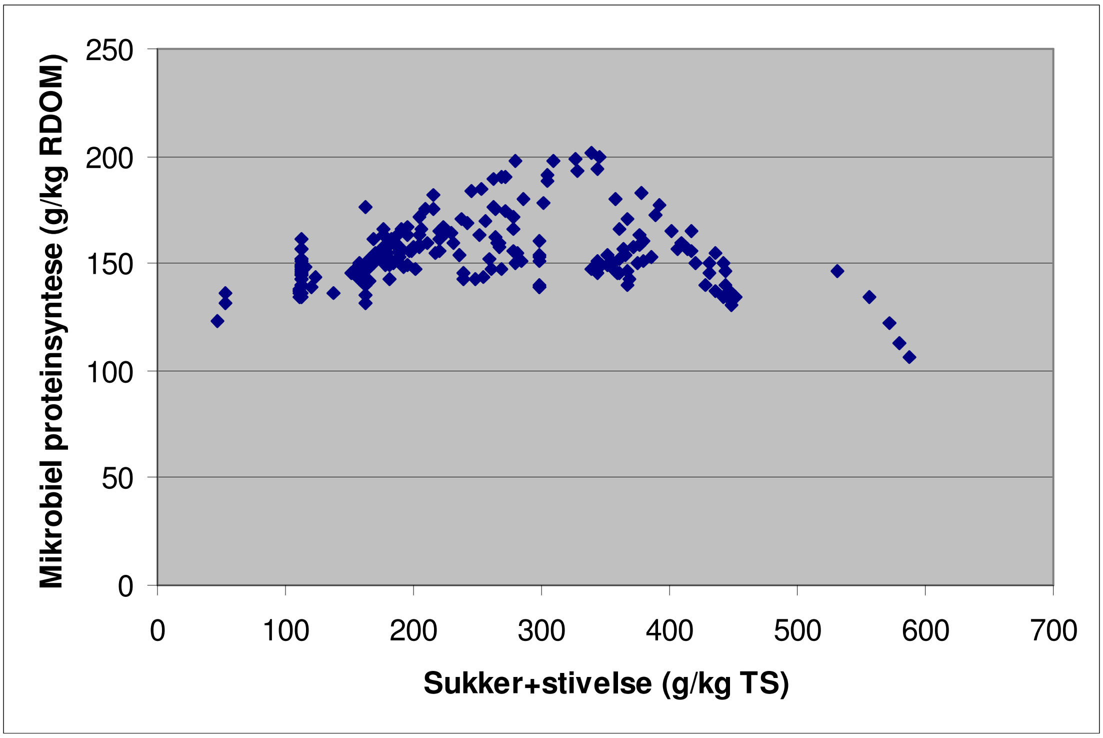
$$\left(\frac{\sum_i DMI_i \cdot ST_i + \sum_i DMI_i \cdot \mathrm{Re}\,stCHOcorr_i}{\sum_i DMI_i}\right)$$

Det fremgår af ligningerne at effektiviteten beregnes ud fra DMI i forhold til kropsvægt samt rationens indhold af restCHO+stivelse. Enheden for effektiviteten i den mikrobielle proteinsyntese er g/kg RDOM (rumen digested organic matter) og det hænger sammen med at effektivitetsværdien, som udregnes i ovenstående ligninger, multipliceres med mængden af vomfordøjeligt organisk stof, når man beregner daglig mængde mikrobielt protein.

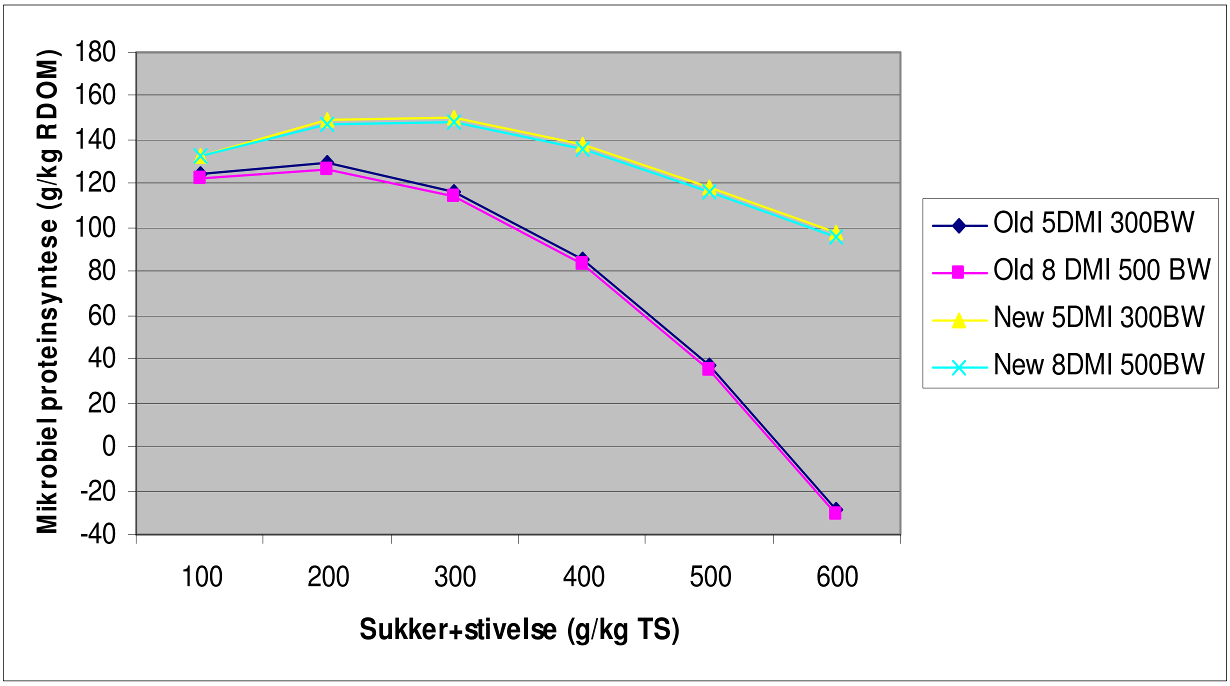
Ændringen i ligningen betyder at proteinsyntesen generelt øges med stigende mængder sukker+stivelse (sukker er egentlig = restkulhydrater = restCHO = primært sukker og pektiner) i rationen, og især ved større mængder (>300 g/kg TS) i rationen (Figur 19). Den nye ligning for beregning af den mikrobielle proteinsyntese betyder næsten ingenting for fordøjeligheden af NDF og organisk stof (Figur 19). Dog ses det, at fordøjeligheden af organisk stof reduceres med 1 til 2%-enheder ved større mængder sukker+stivelse (>550 g/kg TS) i rationen ved brug af den nye ligning (Figur 20). Det skyldes at fordøjeligheden af protein-fraktionen reduceres en smule med den nye ligning i forhold til den gamle ligning.



Figur 17. Sammenhæng mellem vægten af dyret (kvier, stude og tyre) og effektiviteten i den mikrobielle proteinsyntese i vommen beregnet ved den nye ligning. Data fra alle rationer i alle 3 lande. Det er stadig tyrene på den danske ration, der har den laveste effektivitet i den mikrobielle proteinsyntese i forhold til vægt, men proteinsyntesen er ca. 50 g/kg RDOM (rumen digested organic matter) større end i den originale ligning (se figur 13).

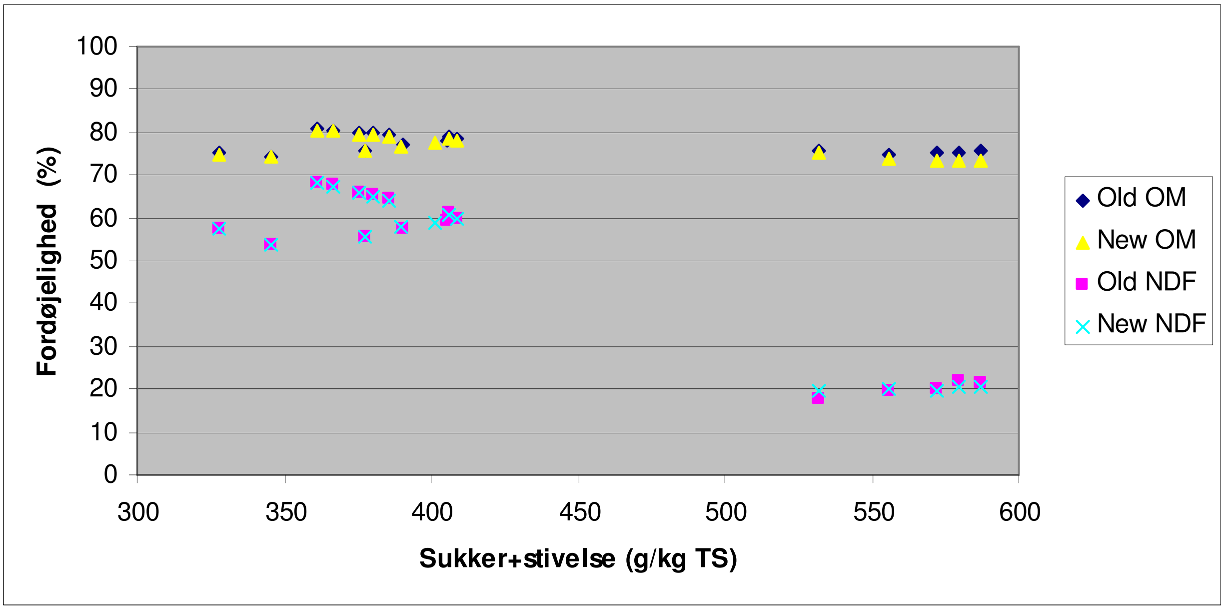


Figur 18. Sammenhæng mellem foderrationens indhold af sukker+stivelse og effektiviteten i den mikrobielle proteinsyntese i vommen beregnet ved den nye ligning. Data fra alle rationer i alle 3 lande. Sammenlignet med figur 12 ses det, at proteinsyntesen øges med den nye ligning ved højere niveauer af sukker+stivelse. RDOM: rumen digested organic matter.



Figur 19. Sammenhæng mellem foderrationens indhold af sukker+stivelse og effektiviteten i den mikrobielle proteinsyntese i vommen beregnet ved den gamle (Old) og nye (new) ligning ved 5 eller 8 kg tørstofoptagelse (DMI) og 300 eller 500 kg kropsvægt (BW: body weight). RDOM: rumen digested organic matter. Der er en relativ stor forskel i mikrobiel proteinsyntese mellem den

nye og gamle ligning, også ved sukker+stivelses niveauer på <400 g/kg TS. Det er muligt at forskellen ved sukker+stivelses niveauer på <400 g/kg TS skal reduceres i fremtiden.



Figur 20. Sammenhæng mellem foderrationens indhold af sukker+stivelse og fordøjeligheden af organisk stof (OM) og NDF i den totale ration med den gamle (Old) og nye (New) ligning til beregning af mikrobiel proteinsyntese i vommen. Data er for tyre på den svenske ration (16 måneder; s+s < 500 g/kg TS) og danske tyre (s+s > 500 g/kg TS).

NDF-digestibility

Appendix 1 gives an overview over trials that have measured the digestibility of different nutrients, especially NDF, in relation to the concentrate/roughage ratio.

Explanations to why the concentrate level does not influence or has a limited influence on the digestibility of the fibre fraction of the feed (cited from Poore et al., 1990):
"The decreased fiber digestion observed when purified starch is added to forage diets (Chappel and Fontenot, 1968; Mulholland et al., 1976) has been difficult to demonstrate by altering the grain to forage ratios in mixed diets (5 ref's from 1970's and 80's). Possible explanations are:

- compensatory digestion of fiber in hindgut (This is partly taken into account in the NorFor Plan system)
- differences in source of fiber
- decreased passage rates for diet components in higher-concentrate diets" (This is taken into account in the NorFor Plan system)

NDF digested in the rumen decreased and postruminal NDF digestion increased when level of corn in the diet increased (Brink & Steele, 1985).
Poore et al. (1990) estimerede, at 54% af den observerede nedgang i NDF-fordøjelighed ved at gå fra 58 til 88% kraftfoder i rationen skyldtes reduktion i kraftfoderets NDF-fraktion.
Passagehastigheden for hvedehalm og lucernehø reduceres ved 88% kraftfoder med henholdsvis 28 og 13%, sammenlignet med 28% kraftfoder (Poore et al., 1990). These values fits well to the new

version of NorFor Plan, where the passage rate of NDF in forage is adjusted for ruminally degraded sugars and starch (vombelastning).

Corn (90% of DMI) in combination with corn-silage (4% of DMI) led to a relatively high NDF-digestibility of 74,5% of which nearly half (34,8%) was digested post-ruminal (Brink & Steele, 1985). Other studies confirm NDF-digestibility's above 55% when corn is the primary concentrate used in the diet (Hannah et al., III, 1990; Buenfil & Loerch I, 2005; Buenfil & Loerch II, 2005). Soita et al. (2003) only found an NDF-digestibility of 37,2% feeding a diet with 20% whole crop barley silage and nearly 80% barley grain. An explanation for this difference between the two studies could be that a high proportion of NDF in corn bypass the rumen, while starch in barley has a high kd, that leads to a depressing effect on cellulolytic microbes.

Diets with wheat straw have low NDF-digestibility's (around 30-35%) (Poore et al., 1990). However these reported NDF- digestibilities are still higher than what NorFor estimates. NorFor estimated an NDF-digestibility of app. 20% in the Danish standard diet for young bulls, where 90% of DMI is concentrate (>90% barley and the rest soybean meal) and the last 10% of DMI is barley straw.

Table 6 compares digestibilities calculated in "NorFor Training Model" with results obtained in trials. The input used in the "NorFor Training Model" was the diet composition, DMI and animal weight reported in the cited papers.

Table 6. Comparison of total tract digestibility's calculated by the Training Model (NorFor) and digestibilities reported in the literature. The input to the Training Model was the ration composition, DMI and animal weight that were used in the experimental studies.

Nutrient	Total digestibility (%)		DMI (kg)	Live weight (kg)[2]	Reference
	NorFor	Litteratur			
NDF	15,1	74,5	6,82 maize 0,51 maize silage[1]	500	Brink & Steele (1985)
OM	82,6	86,4			
NDF	19,1	42,3	0,5 veg. fat 8,2 barley 2,2 barley silage[1]	471	Soita et al. (2003) (long particle size)
OM	74,0	66,9			
NDF	38,3	49,4	0,3 veg. fat 5,4 barley 5,7 barley silage[1]	471	Soita et al. (2003) (long particle size)
OM	73,4	70,0			
NDF	21,4	69,9	0,79 soybean meal 6,06 maize 1,58 maize silage[1]	350	Buenfil & Loerch II (2005)
OM	79,8	83,0			
NDF	15,4	67,1	0,76 soybean meal 7,14 maize 0,45 maize silage[1]	350	Buenfil & Loerch II (2005)
OM	82,0	82,3			

[1] Whole crop silages

[2] The live weight is in most studies reported as initial weight, i.e. the true live weight is likely to be higher due to the daily gain of the young stock. This means that e.g. the true rumen passage rates are a bit lower than what is calculated by NorFor Training Model and therefore that NDF and OM digestibilities are a bit higher.

Table 6 show that NorFor underestimates the digestibility of NDF compared to the literature while the digestibility of OM agrees quite well with the literature. The explanation for this low NDF digestibility is likely to be related to a high passage rate (kp) for NDF, a low digestion rate (kd) for NDF or a combination of those two. The kd for NDF is influenced by the rumen environment in terms of "vombelastning" and Figure 14 indicates that low NDF-digestibility is associated with high levels of S+S. High levels of S+S reduce the digestibility of NDF due to the effect of "vombelastning". In order to judge the impact of "vombelastning", calculations were done in "NorFor Training Model" where the effect of this correction (corrkdNDF) on NDF- and OM-digestibility's was excluded. Results are presented in Table 7.

Table 7. Passage rates of NDF out of the rumen in concentrates (C) and forages (F), intake of NDF, starch and OM and total tract digestibility of NDF, when "corrkdNDF" is excluded from the Training Model[3].

Passage rate F (%/h)[1]	Passage rate C (%/h)[1]	NDF (kg/d)[5]	Starch (kg/d)[5]	OM (kg/d)[5]	NDF digest. excl. corrkdNDF (%)[2]	OM digest. excl. corrkdNDF (%)[2]	Reference
0,11	2,3	0,87	4,5	7,2	53,5 (vs. 74,5)	88,5 (vs. 86,4)	B & S (1985)
0,72	3,5	3,3	-	10,9[4]	53,1 (vs. 42,3)	82,1 (vs. 66,9)	Soita (2003)
1,21	4,2	4,1	-	11,4[4]	51,3 (vs. 49,4)	77,5 (vs. 70,0)	Soita (2003)
0,45	3,6	1,5	5,1	8,3	56,2 (vs. 69,9)	86,2 (vs. 83,0)	B & L (2005)
0,25	3,3	1,3	5,5	8,2	48,5 (vs. 67,1)	86,9 (vs. 82,3)	B & L (2005)

[1] Passage rates of NDF in forages and concentrates are not influenced by corrkdNDF

[2] Compared to the measured digestibility in the literature (see Table 6)

[3] corrkdNDF is an adjustment of the degradation rate (kd) of NDF in the rumen due to "vombelastning" by rumen degraded starch and sugar in the diet.

[4] Dry matter intake.

[5] Values extracted from the literature.

Table 7 continued:

NDF (kg/d)[6]	Starch (kg/d)[6]	OM (kg/d)[6]	NDF C (kg/d)[6]	NDF F (kg/d)[6]	NDF (g/kg BW)[6]	Reference
1,01	5,0	7,2	0,82	0,19	2,0	B & S (1985)
2,40	5,6	10,6	1,46	0,94	5,1	Soita (2003)
3,39	4,8	11,2	0,96	2,43	7,2	Soita (2003)
1,44	4,8	8,2	0,84	0,60	4,1	B & L (2005)
1,13	5,3	8,2	0,96	0,17	3,2	B & L (2005)

[6] Values extracted Training Model.

Table 7 shows that "corrkdNDF" has a rather large impact on the NDF-digestibility since NDF-digestibility increases from typically 15-20% (Table 1) to around 50% (Table 2) and OM-digestibility increases by typically 5%-units. Excluding corrkdNDF leads to a more appropriate digestibility for NDF (Table 2), while the OM-digestibility becomes consistently higher in NorFor compared to the literature.

Precautions should be taken for the comparisons made in Table 6 and 7 for at least 2 reasons:

1) live weight of the animals
2) differences in the feedstuff nutrient characteristics between diets used in the experiments and diets used in the calculations in "NorFor Training Model"

1) The live weight is in most studies reported as initial weight, i.e. the true live weight is likely to be higher due to the daily gain of the young stock. This means that the true value of g NDF/kg BW is a bit lower than what is calculated by "NorFor Training Model" and therefore that the true rumen passage rates for NDF in forages (kpNDFf) are a bit lower than what is calculated by NorFor Training (see effect of NDF/kg BW in Figure 21 and Equation 126). Likewise will a true higher BW decrease the rumen passage rate of NDF in concentrates (kpNDFc, Equation 122). This means that the true digestibility of NDF and OM is higher than what "NorFor Training Model" actually calculates. Also the efficiency in microbial protein synthesis is decreased slightly if BW increases (see Equation earlier in this document).

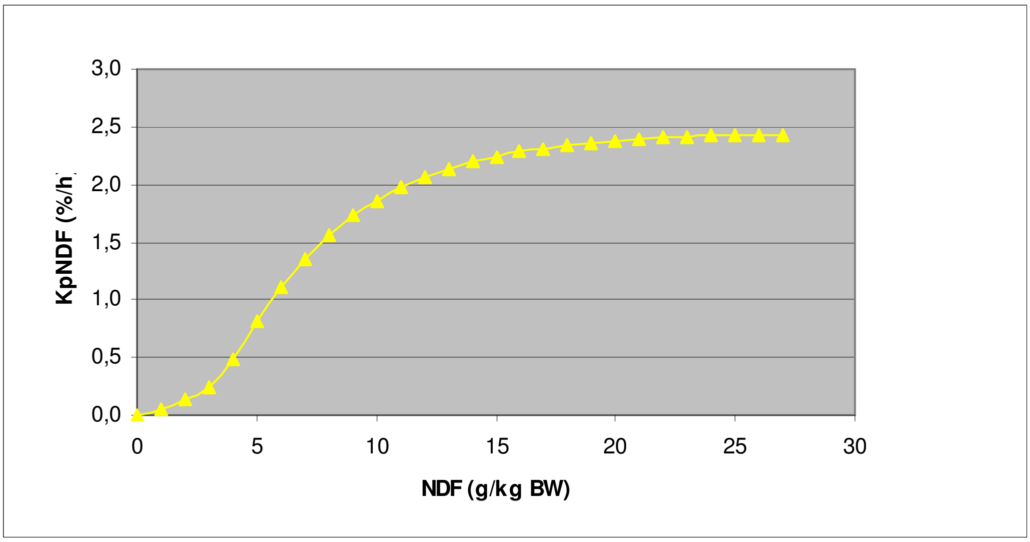


Figure 21. The relationship between the intake of NDF and the passage rate of NDF in forages.

Equation 126:

$$kpNDFf = \left(\frac{-0.00004977 + 0.0284 \cdot \left(\frac{\sum_i DMI_i \cdot NDF_i}{BW\_cur} \right) + 0.01129 \cdot \left(\frac{\sum_i DMI_i \cdot NDF_i}{BW\_cur} \right)^2 - 0.01072 \cdot \left(\frac{\sum_i DMI_i \cdot NDF_i}{BW\_cur} \right)^3 + 0.002185 \cdot \left(\frac{\sum_i DMI_i \cdot NDF_i}{BW\_cur} \right)^4}{1 - 0.4647 \cdot \left(\frac{\sum_i DMI_i \cdot NDF_i}{BW\_cur} \right) + 0.09369 \cdot \left(\frac{\sum_i DMI_i \cdot NDF_i}{BW\_cur} \right)^2 - 0.008468 \cdot \left(\frac{\sum_i DMI_i \cdot NDF_i}{BW\_cur} \right)^3 + 0.0009478 \cdot \left(\frac{\sum_i DMI_i \cdot NDF_i}{BW\_cur} \right)^4} \right) \cdot 0{,}86$$

for the i=1...n'th feedstuff

Equation 122:

$$kpNDFc = \left(2{,}504 + 0{,}1375 \cdot \frac{\sum_i DM_i \cdot 1000}{BW\_cur} - 0{,}02 \cdot \frac{\sum_j DM_j \cdot 100}{\sum_i DM_i} \right) \cdot 0{,}86$$

for the i=1...n'th feedstuff and j'th concentrate

2) Table 7 shows an overall fair agreement for daily intake of NDF, starch and OM between experiments and data used in NorFor Training Model, except for the study by Soita et al. (2003) (Table 7). A comparison of the feedstuffs or diets used in the experiments and NorFor Training Model shows that the reason for this disagreement is caused by the barley silage used in the study by Soita et al. (2003) (Table 8). The higher content of starch in the barley silage used in NorFor

Training Model leads to a lower NDF-digestibility in the rumen and this could explain the higher OM-digestibility by NorFor despite a lower NDF-digestibility (Table 8).

Table 8. Nutrient composition of feedstuffs or diets used in NorFor and experimental studies[1].

Nutrient	B & S (1985) Complete diet[2]	Soita (2003) Barley silage[2]	B & L (2005) Complete diet (low forage)[2]	B & L (2005) Complete diet (high forage)[2]
NDF (% of DM)	12,9 vs. 13,8	47,8 vs. 42,7	12,9 vs. 13,6	15,7 vs. 17,1
Starch (% of DM)	65,5 vs. 68,3	14,1 vs. 25,8	66,1 vs. 63,0	57,8 vs. 57,2

[1] Nutrient's in complete diets and barley silage was extracted from Training Model.

[2] The first number refer to experimental data and the second number refer to data used in Training Model, e.g. for NDF 12,9% refer to the experimental diet and 13,8% refer to the diet used in Training Model.

Conclusion

NorFor estimates lower NDF-digestibility in steers (and most likely young stock in general) compared to data from the literature, whereas OM-digestibility agrees fairly well between NorFor and the literature. The main reason for the lower NDF-digestibility estimated by NorFor is the effect of "vombelastning" on the rumen degradation rate of NDF. Thus, excluding corrkdNDF leads to a more appropriate digestibility for NDF. However, this leads to an OM-digestibility that becomes consistently higher in NorFor compared to the literature.

Changes made in the NorFor digestion model in relation to NDF-digestibility

On a workshop held in Denmark in November 2006 it was decided to change the equations for the rumen passage rate of NDF in forages ($kpNDF_{forage}$) and the correction factor for kdNDF (vombelastning) in order to obtain a higher NDF-digestibility when calculating diets for young stock.

The new equation for calculating $kpNDF_{forage}$:

$$KpNDF_{forage} = (0,48797+0,005686*X^2+0,0013119*X^4)/(1+0,0138591*X^2+0,00051948*X^4)$$

where X = NDF intake (g/kg BW)

gives a higher passage rate compared to the original equation when the NDF intake is ≤5 g/kg BW (Figure 22).

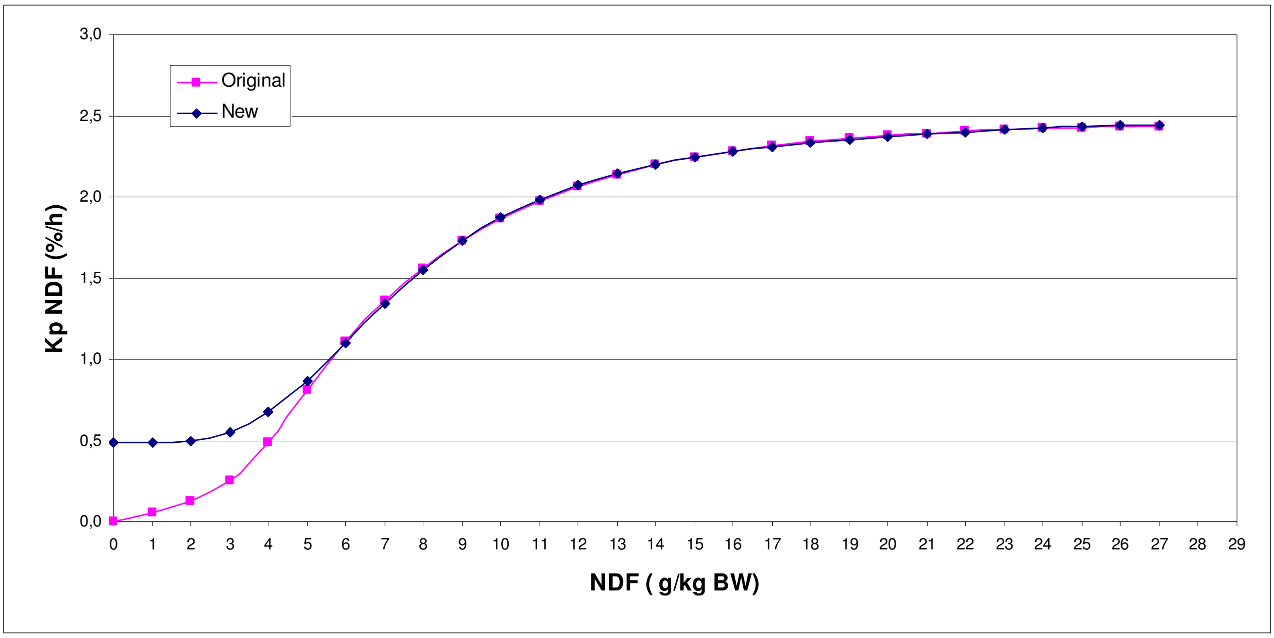


Figure 22. The relationship between intake of NDF and the rumen passage rate of NDF in forages (kpNDF).

The new equation for calculating the correction-factor of kdNDF:

corrkdNDF = 0,4561+0,5431/(1+EKSP(-(X-0,7657)/(-0,1589)))
where X=NDF (g/kg BW)

results in a higher factor compared to the original equation when the "vombelastning" is >1 g/g NDF (Figure 23).

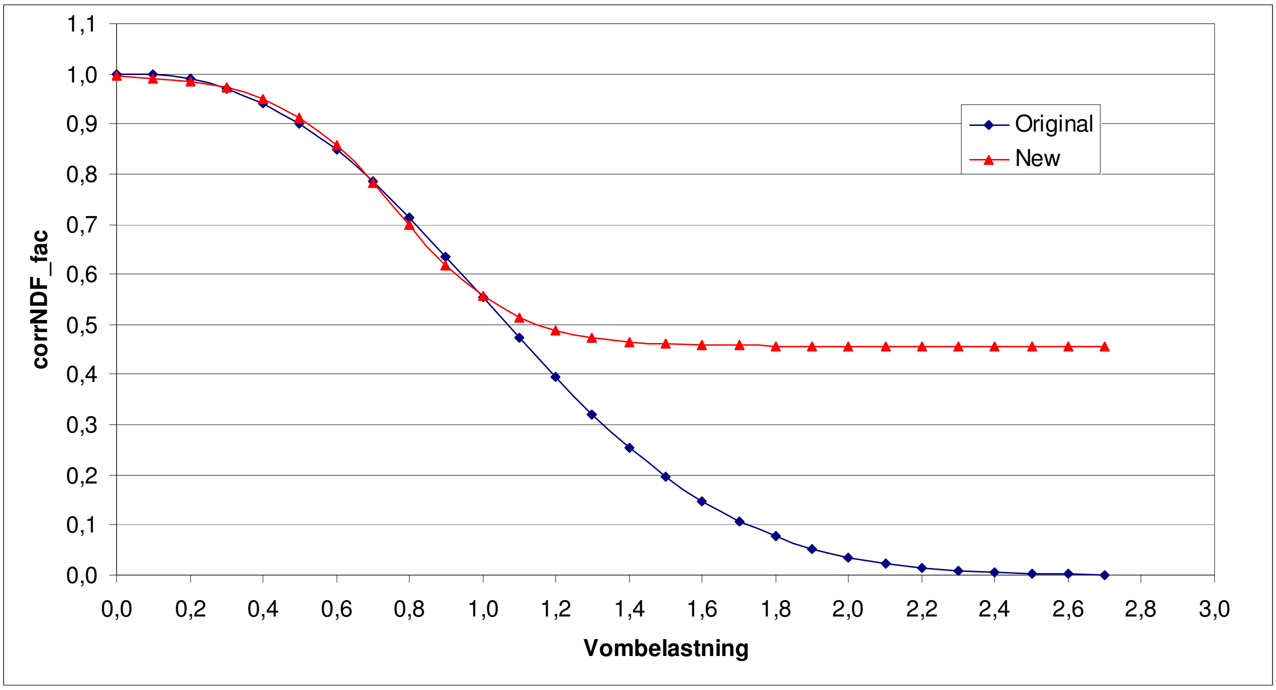


Figure 23. The relationship between "vombelastning" and the correction factor for kdNDF (corrkdNDF). The correction factor is multiplied with the calculated degradation rate of NDF in forages and concentrates.

The consequence of the above-mentioned changes on NDF-digestibility is shown in Table 9. This Table shows that NDF-digestibility is increased considerably compared to the original figures presented in Table 6, although still not as high as reported in the literature. The reason for this increased NDF-digestibility is that a high (>1) vombelastning does not reduce the degradation rate of NDF in the rumen as much as was the case earlier (Table 6). Actually, the change in rumen passage rate of NDF in forages has the opposite effect, i.e. it reduces the NDF-digestibility, because kpNDF increases when the NDF intake is <5 g/kg BW (Figure 22).

Table 9. Passage rate of NDF in forage (F) out of the rumen and total tract digestibility of NDF and OM after changing the calculation of passage rate and the effect of "vombelastning" on kdNDF (see new equations above this Table).

Passage rate (F) (%/h)	NDF digestibility (%)[1]	OM digestibility (%)[1]	Reference
0,43	41,7 (vs. 74,5)	86,7 (vs. 86,4)	B & S (1985)
0,76	42,0 (vs. 42,3)	79,5 (vs. 66,9)	Soita (2003)
1,19	40,9 (vs. 49,4)	74,2 (vs. 70,0)	Soita (2003)
0,60	44,7 (vs. 69,9)	84,1 (vs. 83,0)	B & L (2005)
0,50	37,2 (vs. 67,1)	85,2 (vs. 82,3)	B & L (2005)

[1] Compared to the measured digestibility in the literature (see Table 1 and Appendix 1)

Especially the Danish diet for young bulls led to low NDF-digestibility's of app. 20% (Figure 14) and an OM-digestibility between 73,2 and 75,1%. For these diets the new equations (Figures 22 and 23) result in NDF-digestibility's between 35,3 and 40,0% and OM-digestibility's of 74,2-86,7%.

Since these calculations were made an additional change has been made in the NorFor Plan system. Based on new experimental data a new equation for passage rate of NDF has been developed. In the new equation the passage rate is adjusted for the level of easily fermented carbohydrates in the diet (Vombelastning). This means that the passage rate is decreased when the “Vombelastning” is increased. This will result in an increased NDF digestibility and a decreased protein digestibility, which will improve the calculations.

References

Berg, J. & Matre, T. 2001. Produksjon av storfekjøtt. Landbruksforlaget.

CVB, 2000. Tabellenboek Veevoeding. Centraal Veevoederbureau, Holland.

Gorocica-Buenfil, M. A. & Loerch, S. C. 2005. Effect of cattle age, forage level and corn processing on diet digestibility and feedlot performance. J. Anim. Sci. 83:705-714.

Fisker, I. & Bligaard, H. B. 2004. Nye energinormer til stude. KvægInfo nr. 1337. Accessible on www.lr.dk.kvaeg.informationsserier/lk-meddelelser/1337.

Brandsma, G. 2006. Pers. com.

Brink, D. R. & Steele, R. T. 1985. Site and extent of starch and neutral detergent fibre digestion as affected by source of calcium and level of corn. J. Anim. Sci. 60:1330-1337.

Geay, Y. & Robelin, J. 1979. Variation of meat production capacity in cattle due to genotype and level of feeding: Genotype-nutrition interaction. Livest. Prod. Sci. 6:263-276.

Hannah, S. M., Paterson, J. A., Williams, J. E. & Kerley, M. S. 1990. Effects of corn vs. corn gluten feed on site, extent and ruminal rate of forage digestion and on rate and efficiency of gain. J. Anim. Sci. 68:2536-2545.

MAFF, 1975. Energy allowances and feeding systems for ruminants. Technical Bulletin 33. Ministry of Agriculture, Fisheries and Food. London.

Moore, J. A., Poore, M. H. & Swingle, R. S. 1990. Influence of roughage source on kinetics of digestion and passage, and on calculated extents of ruminal digestion in beef steers fed 65% concentrate diets. J. Anim. Sci. 68:3412-3420.

Olsson, I. & Lindell, L. 2002. Underlag for uppdatering av rekommenderade energigivor till växande ungnöt. Rapport nr. 250. Sveriges Lantbruksuniversitet.

Poore, M. H., Moore, J. A. & Swingle, R. S. 1990. Differential passage rates and digestion of neutral detergent fiber from grain and forages in 30, 60 and 90% concentrate diets fed to steers. J. Anim. Sci. 68:2965-2973.

Robelin, J. & Daenicke, R. 1980. Variations of net requirements for cattle growth with liveweight, liveweight gain, breed and sex. Ann. Zootech. 29:99118.

Soita, H. W., Christensen, D. A. & McKinnon, J. J. 2003. Effects of barley silage, particle silage and concentrate level on rumen kinetic parameters and fermentation patterns in steers. Can. J. Anim. Sci. 533-539.

Strudsholm, F., Aaes, O., Madsen, J., Kristensen, V. F., Andersen, H.R., Hvelplund, T. & Østergaard, S. 1999. Danske fodernormer til kvæg. Landbrugets Rådgivningscenter.

Thorbeck, G. & Henckel, S. 1976. Energetisk vedligeholdsesbehov hos kalve. Statens Husdyrsbrugsforsøg. Meddelelse nr 125.

Van Es, A. J. H. 1975. Feed evaluation for dairy cows. Livest. Prod. Sci. 2:95-107.

Van Es, A. J. H. 1978. Feed evaluation for ruminants. The systems in use from May 1977 onwards in the Netherlands. Livest. Prod. Sci. 5:331-345.

Weisbjerg, M. R. & Hvelplund, T. 1993. Estimation of net energy content in feeds for cattle. Forskningsrapport nr. 3. Statens Husdyrbrugsforsøg.

Bilag 1. Sammenstilling af forsøg, som har undersøgt fordøjeligheden af NDF og organisk stof i ungdyr (stude, tyre og kvier).

Reference	Animals & design	Diet[1]	Treatments	OM digestibility (%)[2]	NDF digestibility (%)[2]	ADF digestibility (%)[2]	Other[2]	DMI
Buenfil & Loerch I (2005)	Steers N=16 BW=254 or 477 kg Group design	80% corn; 9,5% soybean meal; 8% chopped grass hay	Whole or ground corn & age	Whole: 77,3 Ground: 80,3 254BW: 76,8 477BW: 80,7	Whole: 61,5 Ground: 58,0 254BW: 56,6 477BW: 62,9	Whole: 58,2 Ground: 47,5 254BW: 50,0 477BW: 55,7	CP-digestibility Whole: 73,5 Ground: 71,5 254BW: 71,3 477BW: 73,8	6,7 5,7 5,7 6,6
Buenfil & Loerch II (2005)	Steers N=16 BW=350 Group design	69,7 or 83,0% corn; 9,1 or 8,8% soybean meal; 18,2 or 5,2% corn silage	High or low forage	High: 83,0 Low: 82,3	High: 69,9 Low: 67,1	High: 64,4 S Low: 57,2 S	CP-digestibility High: 78,5 Low: 77,2	8,7 8,6
Poore et al. (1990)	Steers N=6 BW=509 Latin Sq design	70, 40 or 10% forage (50% chopped alfalfa hay & 50% chopped wheat straw); 27,6, 57,7 or 87,5% sorghum grain	Forage/concentrate ratio	70/28: 63,6 40/58: 70,3 10/88: 80,0 Det er DM fordøjelighed Linear effect	70/28: 41,0 40/58: 35,6 10/88: 33,1 PDF[3]: 70/28: 92,4 S 40/58: 70,3 S 10/88: 48,0 S Ruminal NDF: Hay: 70/28: 24,5 40/58: 24,6 10/88: 10,7 S Straw: 70/28: 21,7 40/58: 21,7 10/88: 6,0 S Sorghum: 70/28: 40,6 40/58: 42,8	Rumen passage rate (%/h): Hay: 70/28: 4,6 40/58: 4,7 10/88: 4,1 S Straw: 70/28: 3,4 40/58: 3,0 10/88: 2,2 S Sorghum: 70/28: 5,3 40/58: 5,1 10/88: 4,4 Liquid: 70/28: 9,3 40/58: 10,0 10/88: 8,2	Rumen fill (kg DM): 70/28: 4,5 40/58: 4,3 10/88: 4,1	$7,2^{a}$ $8,3^{b}$ $7,9^{b}$ %ofBW: $1,44^{a}$ $1,64^{b}$ $1,55^{ab}$

					10/88: 28,4 S			
Brink & Steele (1985)	Steers N=5 BW=509 Youden Sq design	44, 24 or 4% corn silage; 50, 70 or 90% corn	Forage/concentrate ratio	44/50: 79,0 24/70: 83,3 4/90: 86,4 Linear effect	44/50: 77,4 24/70: 77,1 4/90: 74,5 Ruminal: 44/50: 74,9 24/70: 69,4 4/90: 34,8 Linear effect			8,7 8,1 7,2 (OM-intake)
Soita et al. (2003)	Steers N=4 BW=471 Latin Sq design	50 or 20% whole crop barley silage; 50 or 80% concentrate of which 90% was barley	Forage/concentrate ratio & particle size (PS) of silage (5 (S) or 19 (L) mm)	L50: 70,0 L20: 66,9 S S50: 66,6 S20: 64,4 S Det er DM fordøjelighed Effekt af F/C-ratio og PS	L50: 49,4 L20: 42,3 S S50: 41,6 S20: 37,2 S Effekt af F/C-ratio og PS	L50: 41,3 L20: 26,7 S S50: 35,1 S20: 22,1 S Effekt af F/C-ratio og PS		11,4 10,9 12,6 12,3
Hannah et al. (1990) I	Heifers N=5 BW=216 (initial weight) Latin Sq design	Alfalfa haylage substituted with corn gluten feed (CGF) replacing 0, 20, 40, 60 or 80% of haylage DM. Diets were restricted to 2% of BW.	Forage/concentrate ratio	CGF0: 36,9 CGF20: 44,3 CGF40: 46,9 CGF60: 53,6 CGF80: 60,2 Linear effect	CGF0: 36,9 CGF20: 47,4 CGF40: 47,5 CGF60: 50,7 CGF80: 56,7 Linear effect Ruminal: CGF0: 32,7 CGF20: 39,2 CGF40: 38,1 CGF60: 39,6 CGF80: 47,6 Linear effect	CGF0: 28,5 CGF20: 46,7 CGF40: 39,9 CGF60: 40,6 CGF80: 35,4 Quadratic effect Ruminal: CGF0: 22,0 CGF20: 30,7 CGF40: 21,7 CGF60: 21,0 CGF80: 25,0 Cubic effect		10,8 10,6 10,6 10,6 10,8 (this correspond to 500 kgBW?)
Hannah et al. (1990)	Steers N=8	Alfalfa haylage substituted with	Forage/concentrate	C0: 52,3 C20: 59,9	C0: 44,2 C20: 43,5	C0: 45,3 C20: 49,3		5,6 6,3

II	BW=306 (initial weight) Latin Sq design	cracked corn replacing 0, 20, 40 or 60% of haylage DM. Diets were restricted to 2% of BW	ratio	C40: 67,9 C60: 73,5 Linear effect	C40: 47,7 C60: 50,4 Linear effect	C40: 50,2 C60: 54,3 Linear effect		6,4 6,5 (OM-intake)
Hannah et al. (1990) III	Bulls N=20 BW=276 (initial weight) Group design	100% alfalfa haylage substituted with 2 levels (20 or 60%) of corn or 2 levels (20 or 60%) of CGF. Diets were restricted to 2% of BW	% corn & % CGF	100A: 52,0 20C: 56,8 60C: 60,1 20CGF: 57,9 60CGF: 71,4S Effect of 100A vs supplemented diets	100A: 52,0 20C: 56,8 60C: 60,1 20CGF: 57,9 60CGF: 71,4S Effect of 100A vs supplemented diets	100A: 45,4 20C: 45,3 60C: 44,8 20CGF: 46,6 60CGF: 50,9 Effect of source of supplement		4,5 5,3 5,4 4,8 5,4 (OM-intake)
Moore et al. (1990)	Steers N=6 BW=299 Latin Sq design	AH: chopped alfalfa hay (34,4%), flaked milo (57,4%) and molasses (4,8%). WS: chopped alfalfa hay (17,2%), chopped wheat straw (17,2), flaked milo (56,0%) and molasses (4,8%).	Roughage source	AH: 80,3 WS: 79,4 Ruminal: AH: 67,5 WS: 63,8	AH: 56,4 WS: 51,6 Ruminal: AH: 28,1 WS: 32,0		Rumen passage rate (%/h): AH-diet: AH: 5,0 Milo: 5,7 Liquid: 8,7 WS-diet: AH: 4,9 WS: 2,7 Milo: 5,4 Liquid: 8,8	5,9 6,2

[1] Summer ikke til 100%, da resten er mineraler, vitaminer, urea etc.

[2] Hvis der ikke er angivet noget "S", er der ingen signifikant effekt af behandling. Der er tale om "total tract apparent digestibility".

[3] PDF: potentially digested NDF. Defined by 72-h in situ disappearance in one steer fed with 60% concentrate.