

NorFor – The Nordic feed evaluation system



EAAP – European Federation of Animal Science



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Preface

The present volume is the first comprehensive, published description of the Nordic Feed Evaluation System, NorFor. It includes the results of extensive work initiated as a project in 2001 by the farmers' dairy cooperatives in Denmark, Norway, Iceland and Sweden. The overall aim was to create an identical, common feed evaluation system for all four countries to facilitate communication between farmers, consultants and feed industry representatives. Additional goals were to make dissemination of relevant research findings faster and more efficient, both within the four countries and internationally.

Towards that end, a group of experts in ruminant nutrition was commissioned to develop such a system. Since we regarded this as a request to overhaul the current national systems comprehensively, we concluded that it provided an opportunity to develop a completely new feed evaluation system based robustly on current, published knowledge.

NorFor was a development project that ran from 2002 to 2006 and included comparisons of various feed evaluation systems applied in western countries. The development also included validation of the models based on available research data from the Nordic countries. Significant parts of the development work involved close cooperation with scientists at the agricultural universities and research institutes in the Nordic countries. In addition, we have shared information and have had constructive discussions with experts in the feed industry and feed laboratories. We greatly appreciate the past and ongoing cooperation. From 2007 onwards, NorFor has been jointly funded and managed by the four organizations mentioned above through a cooperative organization (NorFor F.M.B.A.).

The present description of NorFor includes all parts of the model. References to the most important sources of information are also given. We thereby provide a description of the biological basis for NorFor. The NorFor project group hopes this volume will be useful for dairy farmers, advisors, scientists and all other actors in the dairy industry in the four NorFor countries. We also recommend the reader to use the IT tools, since many of the nutritional interactions in the model are easier to use and understand if they are applied than if the texts, tables and graphs are read.

NorFor

Anders H. Gustafsson

Leader of NorFor 2002-2009

Acknowledgements

This publication summarizes the entire work of NorFor, including development and documentation. Numerous people have contributed to the compilation of this written document. NorFor has been developed over several years, thus the nature of their contributions has differed greatly. However, despite these differences, every contribution was equally appreciated. Thus, NorFor F.M.B.A. and the authors would like to sincerely thank everyone who has contributed to the project, and to this first version of the NorFor scientific publication.

The main author of the present publication was Harald Volden, of TINE and the Norwegian University of Life Sciences, who has been the leader of the NorFor scientific development group.

In addition, various people have played important roles in preparing the publication, including: Nicolaj I. Nielsen of AgroTech and the Danish Cattle Association; Maria Åkerlind of the Swedish Dairy Association; and Peder Nørgaard of the University of Copenhagen. Other persons, listed in the relevant chapters in this publication, have also contributed as authors.

In addition, the following persons (in alphabetical order of family names) have contributed in different working groups during the development and/or documentation of NorFor:

- Feed evaluation and feeding standards:
Ole Aaes, Jan Bertilsson, Anders H. Gustafsson, Øystein Havrevoll, Márten Hetta, Mogens Larsen, Maria Mehlqvist, Elisabeth Nadeau, Nicolaj I. Nielsen, Peder Nørgaard, Åshild Randby, Arnt Johan Rygh, Ingunn Schei, Harald Volden and Maria Åkerlind
- Feed analysis and tables:
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- IT-system:
Johannes Frandsen, Henrik D. Rokkjær, Anders Göran (Tomlab), Niels Jafner, Ågot Ligaarden, Aud Elin Rivedal and Harald Volden
- Communication:
Marie Liljeholm, Maria Mehlqvist and Arnt Johan Rygh
- National advisory tools:
Åse Marit Flittie Anderssen, Henrik Martinussen, Patrik Nordgren, Berglind Ósk Óðinsdóttir and Maria Åkerlind.

We would also like to thank all scientists who have contributed to fruitful discussions and made valuable comments on the model and documents.

The present documentation was reviewed by Torben Hvelplund, University of Aarhus, Denmark, and Peter Udén, Swedish University of Agricultural Sciences, Sweden and they are greatly acknowledged for their work.

Responsibility for the final content of the model and this present EAAP publication of the NorFor systems rests entirely with the authoring group and NorFor F.M.B.A.

Glossary

Abbreviation	Unit	Parameter name
AA		Amino acids
AA-N	g N/100 g N	Amino acid nitrogen in feedstuff
AA _j		Individual amino acid
AA _i -AAT _N		Individual amino acid absorbed in small intestine
AAT _N	g/d	Amino acids absorbed in the small intestine
AAT _{N-bal}	%	AAT balance
AAT _{N-dep}	g/d	AAT for deposition in cows
AAT _{N-Eff}	%	AAT efficiency of utilisation
AAT _{N-gain}	g/d	AAT requirement for weight gain in primiparous cows and growing cattle
AAT _{N-gest}	g/d	AAT requirement for gestation in cows and heifers
AAT _{N-maint}	g/d	AAT requirement for maintenance
AAT _{N-milk}	g/d	AAT requirement for milk production
AAT _{N-mob}	g/d	AAT for mobilisation in cows
AAT _{N-NEG}	g/MJ	Available AAT to energy ratio in growing cattle
AAT _{N-NEG_Min}	g/MJ	AAT/NEG minimum recommendation
AAT _{N-NEL}	g/MJ	Available AAT to energy ratio in cows
AAT _{N20}	g/kg DM	Standard feed value for AAT at 20 kg DMI
AAT _{N8}	g/kg DM	Standard feed value for AAT at 8 kg DMI
ACF	g/kg DM	Acetic acid in feedstuff
ADG	g/d	Average daily body weight gain
ADG_calc	g/d	Estimated daily weight gain
Age	days	Current age
Age_end	days	Age at calving or sale
Age_start	days	Age at the start of a feeding period
ALF	g/kg DM	Alcohol in feedstuff
APL		Animal production level
Avail_AAT	g/d	Available AAT for milk production
b_car	mg/kg DM	Beta-carotene in feedstuff
BCS		Body condition score, from 1 to 5
BCS_change	BCS/d	Daily change in body condition score
BCS_kg	kg/BCS	Weight per unit body condition score
BUF	g/kg DM	Butyric acid in feedstuff
BW	kg	Current body weight
BW_birth	kg	Body weight at birth
BW_calc	kg	Calculated body weight at a given age
BW_end	kg	Body weight at calving or sale
BW_mat	kg	Body weight for a mature animal
BW_start	kg	Body weight at the start of a feeding period
C12:0	g/100 g FA	Lauric acid in feedstuff
C14:0	g/100 g FA	Myristic acid in feedstuff
C16:0	g/100 g FA	Palmitic acid in feedstuff
C18:0	g/100 g FA	Stearic acid in feedstuff
C18:1	g/100 g FA	Oleic acid in feedstuff
C18:2	g/100 g FA	Linoleic acid in feedstuff
C18:3	g/100 g FA	Linolenic acid in feedstuff
C20:5	g/100 g FA	EPA, Eicosapentaenoic acid in feedstuff

Abbreviation	Unit	Parameter name
C22:6	g/100 g FA	DHA, Docosahexaenoic acid in feedstuff
Ca	g/kg DM	Calcium in feedstuff
Ca_gain	g/d	Calcium requirement for weight gain in growing cattle and primiparous cows
Ca_gest	g/d	Calcium requirement for gestation
Ca_intake_Min	g/d	Calcium minimum recommendation
Ca_main	g/d	Calcium requirement for maintenance
Ca_milk	g/d	Calcium requirement for milk production
CAD	mEq/kg DM	Cation anion difference in feedstuff
CFat	g/kg DM	Crude fat in feedstuff
CFatD	%	Apparent total digestibility of crude fat
CHO		Carbohydrates
CHOD	%	Apparent total digestibility of carbohydrates
CI	min/kg DM	Chewing index of feedstuff
Cl	g/kg DM	Chloride in feedstuff
Cl_gain	g/d	Chloride requirement for weight gain in growing cattle and primiparous cows
Cl_gest	g/d	Chloride requirement for gestation
Cl_intake_Min	g/d	Chloride minimum recommendation
Cl_main	g/d	Chloride requirement for maintenance
Cl_milk	g/d	Chloride requirement for milk production
Co	mg/kg DM	Cobalt in feedstuff
conc_share	% of DM	Concentrate share in ration
corrNDF_fac		Correction factor for kdNDF
CP	g/kg DM	Crude protein in feedstuff
CP_intake	g/d	Daily intake of crude protein
CPcorr	g/kg DM	Crude protein corrected in feedstuff
CPD	%	Apparent total digestibility of crude protein
CT _o	min/kg NDF	Observed chewing time
Cu	mg/kg DM	Copper in feedstuff
DIM	days	Days in milk
DH		Danish Holstein
DM	g/kg	Dry matter in feedstuff
DM1	g/kg	Dry matter, first step
DM2	g/kg DM1	Dry matter, second step
DM _{corr}	g/kg	Dry matter, corrected for volatile losses
DM _{uncorr}	g/kg	Dry matter, not corrected for volatile losses
DMI	kg DM/d	Dry matter intake
DMic	kg DM/d	Dry matter intake of concentrate
DMI _{std}	8 or 20 kg DMI	Dry matter intake when calculating standard feed values
EB	%	Energy balance
EBW	kg	Empty body weight
EBWG	g/d	Empty body weight gain
ECM	kg/d	Energy corrected milk
ECM_response	kg/d	Predicted ECM response
ECMherd	kg/d	Average daily ECM yield per cow in the herd
e_Comp	g/100g	Amino acid composition in endogenous amino acids
eCP	g/d	Endogenous crude protein
ED		Efficient degradability

Abbreviation	Unit	Parameter name
EFOS	% of OM	Organic matter digestibility of feedstuff (EFOS method)
EI	min/kg DM	Eating index
Ep	MJ/MJ	Energy retained as protein
erd		Effective rumen degradability
erd_CP	%	Effective rumen degradation of crude protein
erd_NDF	%	Effective rumen degradation of NDF
erd_RestCHO	%	Effective rumen degradation of residual fraction
erd_ST	%	Effective rumen degradation of starch
ET _o	min/kg NDF	Observed eating time
f_milk	g/kg milk	Observed or expected fat content in milk
FA	g/kg CFat	Fatty acids in feedstuff
FA<C12	g/kg CFat	Sum of fatty acids with less than 12 carbons
FAS		Feed analysis system
Fat_mass	kg	Fat mass
Fe	mg/kg DM	Iron in feedstuff
FFM	kg	Fat free mass
FOF	g/kg DM	Formic acid in feedstuff
FPF	g/kg DM	Fermentation products in feedstuff
FRC	none	Feed ration calculator
FV	FV/kg DM	Fill value of feedstuff
FV_intake	FV/d	Intake of fill value
FV_MR	none	Fill value metabolic regulation factor
FV_r	FV/kg DM	Fill value roughage
FV_SubR	none	Fill value substitution rate factor
FVcorr		Fill value corrected for ammonia and acids
gain_fat	g/d	Daily fat gain
gain_prot	g/d	Daily protein gain
gain_response _{AAT}	g/d	Predicted weight gain from available AAT _N
gain_response _{NEG}	g/d	Predicted weight gain from available energy
GE	MJ/d	Gross energy
gest_day	days	Days of gestation
I	mg/kg DM	Iodine in feedstuff
IB		Icelandic breed
iCP	g/kg CP	Indigestible crude protein in feedstuff
IC	FV/d	Intake capacity
IC_bull	FV/d	Growing bulls intake capacity
IC_cow	FV/d	Intake capacity of lactating cows
IC_dry	FV/d	Intake capacity of dry cows
IC_exercise		Effect of exercise on intake capacity
IC_gest		Effect of gestation on intake capacity
IC_heifer	FV/d	Growing heifers intake capacity
IC_Jersey	FV/d	Intake capacity of growing cattle of Jersey breed
iNDF	g/kg NDF	Indigestible NDF in feedstuff
iST	g/kg ST	Indigestible starch in feedstuff
IVOS	% of OM	Organic matter digestibility of feedstuff (IVOS method)
JER		Jersey
K	g/kg DM	Potassium in feedstuff
K_excreted	g/d	Potassium excreted in faeces and urine

Abbreviation	Unit	Parameter name
K_gain	g/d	Potassium requirement for weight gain in growing cattle and primiparous cows
K_gest	g/d	Potassium requirement for gestation
K_intake_Min	g/d	Potassium minimum recommendation
K_main	g/d	Potassium requirement for maintenance
K_milk	g/d	Potassium requirement for milk production
K_u	g/d	Potassium utilization total
K_u_pct	%	Potassium utilization
kd	%/h	Fractional degradation rate
kdCP	%/h	Degradation rate of potentially degradable crude protein in feedstuff
kdNDF	%/h	Degradation rate of potentially degradable NDF in feedstuff
kdRestCHO	%/h	Degradation rate of rest fraction in feedstuff
kdST	%/h	Degradation rate of potentially degradable starch in feedstuff
k _g	MJ/MJ	Utilisation of ME to NE for growth
k _{g-corr}	MJ/MJ	Utilisation of ME to NE for growth
k _m	MJ/MJ	Utilisation of ME to NE for maintenance
k _{mg}	MJ/MJ	Utilisation of ME to NE for growth and maintenance
kp	%/h	Fractional passage rate
l_milk	g/kg milk	Observed or expected lactose content in milk
LAF	g/kg DM	Lactic acid in feedstuff
li_mCFat	g/d	Microbial crude fat synthesis in the large intestine
li_mCP	g/d	Microbial protein synthesis in the large intestine
lid_NDF	g/d	NDF digested in the large intestine
lid_ST	g/d	Starch from feed digested in the large intestine
m_Comp	g/100 g	Individual amino acid composition of microbial amino acids
MBT	none	Mobile bag technique
mCFat	g/d	Microbial crude fat
mCP	g/d	Microbial crude protein
ME	MJ/d	Metabolizable energy
Mg	g/kg DM	Magnesium in feedstuff
Mg_gain	g/d	Magnesium requirement for weight gain in growing cattle and primiparous cows
Mg_gest	g/d	Magnesium requirement for gestation
Mg_intake_Min	g/d	Magnesium minimum recommendation
Mg_main	g/d	Magnesium requirement for maintenance
Mg_milk	g/d	Magnesium requirement for milk production
Mn	mg/kg DM	Manganese in feedstuff
Mo	mg/kg DM	Molybdenum in feedstuff
MP	g/d	Metabolizable protein
MPY	g/d	Milk protein yield
MRT	H	Mean retention time in the rumen
MR		Effect of metabolic regulation on intake capacity
mST	g/d	Microbial starch in the rumen
MY	kg/d	Milk yield
N		Nitrogen

Abbreviation	Unit	Parameter name
N_excreted	g/d	Nitrogen excreted in faeces and urine
N_faeces	g/d	Nitrogen excreted in faeces
N_gain	g/d	Nitrogen utilization for weight gain in primiparous cows and growing cattle
N_gest	g/d	Nitrogen utilization for gestation
N_milk	g/d	Nitrogen utilization for milk
N_u	g/d	Nitrogen utilization total
N_u_pct	%	Nitrogen utilization
N_urine	g/d	Nitrogen excreted in urine
N_urine_pct	%	Nitrogen excreted in urine (percentage)
Na	g/kg DM	Sodium in feedstuff
Na_gain	g/d	Sodium requirement for weight gain in growing cattle and primiparous cows
Na_gest	g/d	Sodium requirement for gestation
Na_intake_Min	g/d	Sodium minimum recommendation
Na_main	g/d	Sodium requirement for maintenance
Na_milk	g/d	Sodium requirement for milk production
NDF	g/kg DM	Neutral detergent fibre in feedstuff
NDFD	%	Apparent total digestibility of NDF
NDFIr	kg/d	Intake of roughage NDF
NDFr	g/kg DM	NDF in roughage
NDS	g/kg DM	Neutral detergent solubles
NDSd	g/g	Digested neutral detergent solubles
NE	none	Net energy
NE_gest	MJ/d	Net energy requirement for gestation
NE_maint	MJ/d	Net energy requirement for maintenance
NEG	MJ/d	Net energy growth
NEG_bal	%	Energy balance for growing cattle
NEG_DM	MJ/kg DM	Net energy growth
NEG_gain	MJ/d	Energy requirement for growth of growing cattle
NEL	MJ/d	Net energy lactation
NEL ₂₀	MJ/kg DM	Standard feed value for NEL at 20 kg DMI
NEL ₈	MJ/kg DM	Standard feed value for NEL at 8 kg DMI
NEL_bal	%	Energy balance for cows
NEL_dep	MJ/d	Energy requirement for deposition in cows
NEL_DM	MJ/kg DM	Net energy for lactation in ration
NEL_gain	MJ/d	Energy requirement for weight gain in primiparous cows
NEL_milk	MJ/d	Energy requirement for milk production
NEL_mob	MJ/d	Energy supply from mobilisation in cows
NEL_variable	%	Energy balance variable, depending on mobilisation and deposition
NH ₃ N	g N/ kg N	Ammonia nitrogen in feedstuff
NIRS	none	Near infrared spectroscopy
NR		Norwegian Red
OM	g/kg DM	Organic matter in feedstuff
OMD	%	Apparent total digestibility of organic matter
P	g/kg DM	Phosphorus in feedstuff
P_excreted	g/d	Phosphorus excreted in faeces and urine

Abbreviation	Unit	Parameter name
P_gain	g/d	Phosphorus requirement for weight gain in growing cattle and primiparous cows
P_gest	g/d	Phosphorus requirement for gestation
P_intake_Min	g/d	Phosphorus minimum recommendation
P_main	g/d	Phosphorus requirement for maintenance
p_milk	g/kg milk	Observed or expected protein content in milk
P_milk	g/d	Phosphorus requirement for milk production
P_u	g/d	Phosphorus utilization, total
P_u_pct	%	Phosphorus utilization
PBV _N _DM_Min	g/kg DM	Minimum recommendation of PBV _N
PBV _N	g/d	Protein balance in rumen, total
PBV _{N20}	g/kg DM	Standard feed value for PBV at 20 kg DMI
PBV _{N8}	g/kg DM	Standard feed value for PBV at 8 kg DMI
pdCP	g/kg CP	Potentially degradable crude protein in feedstuff
pdNDF	g/kg NDF	Potentially degradable NDF in feedstuff
pdST	g/kg ST	Potentially degradable starch in feedstuff
PL	mm	Most frequent particle length of feedstuff
PRF	g/kg DM	Propionic acid in feedstuff
Protein_mass	kg	Protein mass
Protein_respons	g/d	Predicted milk protein yield
q		Ratio between ME and GE
r_emCP	g/kg rd OM	Efficiency of microbial protein synthesis in the rumen
r_kp1	%/h	Rumen passage rate of NDF particles>6mm from pool 1 to 2
r_kp2	%/h	Rumen passage rate of NDF particles>6mm from pool 2
r_kpc	%/h	Rumen passage rate of protein and starch particles<=6mm
r_kpl	%/h	Rumen passage rate of liquid
r_kpNDFc	%/h	Rumen passage rate of NDF particles<=6mm
r_kpNDFr	%/h	Rumen passage rate NDF particles>6mm
r_kpr	%/h	Rumen passage rate of protein and starch particles>6mm
r_mAA	g/d	Microbial synthesis of amino acids in the rumen
r_mCFat	g/d	Microbial crude fat synthesis in the rumen
r_mCP	g/d	Microbial protein synthesis in the rumen
r_mOM	g/d	Microbial synthesis of organic matter in the rumen
r_mST	g/d	Microbial starch synthesis in the rumen
r_outOM	g/d	Passage of organic matter to small intestine
RD		Red Danish
rd_CFat	g/d	Crude fat degraded in the rumen
rd_CP	g/d	Crude protein degraded in the rumen
rd_CPcorr	g/d	Corrected crude protein degraded in the rumen
rd_FPF	g/d	Fermentation products from feed degraded in the rumen
rd_NDF	g/d	NDF degraded in the rumen
rd_NH ₃ N_CP	g/d	NH ₃ -crude protein degraded in the rumen
rd_OM	g/d	Rumen degraded organic matter

Abbreviation	Unit	Parameter name
rd_pdCP	g/d	Potentially degradable crude protein degraded in the rumen
rd_pdNDFc	g/d	Potentially degradable NDF in concentrate degraded in the rumen
rd_pdNDFr	g/d	Potentially degradable NDF in roughage degraded in the rumen
rd_pdST	g/d	Potentially degradable starch degraded in the rumen
rd_RestCHO	g/d	Rest CHO fraction degraded in the rumen
rd_sCP	g/d	Soluble crude protein degraded in the rumen
rd_sST	g/d	Soluble starch degraded in the rumen
rd_ST	g/d	Total starch degraded in the rumen
RestCHO	g/kg DM	Rest fraction in feedstuff
RestCHOcorr	g/kg DM	Rest fraction corrected in feedstuff
RFA	g/kg CFat	Residual fatty acids
RI	min/kg DM	Rumination index
RLI	g/g NDF	Rumen load index, rumen degraded starch and rest fraction per unit of NDF
Rough_share	% of DM	Roughage percentage in the diet
roughage_appetite	%	Roughage appetite proportion
RT ₀	min/kg NDF	Observed ruminating time
RUP		Rumen undegradable protein
S	g/kg DM	Sulphur in feedstuff
s+pdCP	g/kg CP	Sum of sCP and pdCP in feedstuff
sCP	g/kg CP	Soluble crude protein in feedstuff
Se	mg/kg DM	Selenium in feedstuff
si_outOM	g/d	Passage of organic matter to the large intestine
sid_AA	g/d	Amino acids from feed digested in the small intestine
sid_AA _j		Individual amino acids from feed digested in the small intestine
sid_CFat	g/d	Crude fat from feed digested in the small intestine
sid_CP	g/d	Crude protein from feed digested in the small intestine
sid_eAA	g/d	Endogenous amino acids digested in the small intestine
sid_mAA	g/d	Microbial amino acids digested in the small intestine
sid_mCP	g/d	Microbial crude protein digested in the small intestine
sid_mFA	g/d	Microbial fatty acids digested in the small intestine
sid_mST	g/d	Microbial starch digested in the small intestine
sid_ST	g/d	Starch from feed digested in the small intestine
SH		Swedish Holstein
SR		Swedish Red
sST	g/kg ST	Soluble starch in feedstuff
ST	g/kg DM	Starch in feedstuff
ST_SU_DM	g/kg DM	Content of starch and sugar in the diet
ST_SU_intake	g/d	Total intake of starch and sugar
STD	%	Apparent total digestibility of starch
SU	g/kg DM	Sugar in feedstuff

Abbreviation	Unit	Parameter name
SubR	none	Substitution rate
TAF	g/kg DM	Total acids in feedstuff
TCL	mm	Theoretical cutting length
td_CFat	g/d	Total apparently digested crude fat
td_CHO	g/d	Total apparently digested carbohydrates
td_CP	g/d	Total apparently digested crude protein
td_CPcorr	g/d	Total apparently digested crude protein corrected
td_OM	g/d	Total apparently digested organic matter
TMR	g/kg DM	Total mixed ration
uNDF	g/kg DM	Undegraded NDF
uNDS	g/kg DM	Undegraded neutral detergent solids
uOM	g/g	Undegraded organic matter
Urea N		Urea nitrogen
VFA		Volatile fatty acids
VitA	1000 IU/kg DM	Vitamin A in feedstuff
VitD	1000 IU/kg DM	Vitamin D in feedstuff
VitE	IU/kg DM	Vitamin E in feedstuff
VOS	% of OM	Organic matter digestibility of feedstuff <i>in vitro</i> (VOS method)
YHerd	kg ECM/year	Yield level in the herd
Zn	mg/kg DM	Zinc in feedstuff
WPC	weeks	Weeks post calving