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Energy systems for ruminants

FRIK SUNDSTØL
Department of Animal Science, Agricultural University of Norway, N-1432 Ås-NLH, Norway

SUMMARY

A survey is made of some current energy evaluation systems for ruminants. Estimations have shown that net energy lactation (NE_l) according to van Es and Scandinavian feed unit (SFU) according to Møller *et al.* seem to give the best fit when comparing predicted and observed milk yield.

Despite the fact that all systems apparently have their shortcomings, it is concluded that there is still a need for an energy evaluation system for ruminants. Furthermore, there would be great practical advantages if a common system for energy evaluation in Europe could be agreed upon.

For ration formulation and optimalization the various components (substrates) of the feeds will be of increasing importance.

Key words: comparison, energy, ruminants, systems.

YFIRLIT

Orkumatskerfi fyrir jórturdýr

Í greininni er yfirlit um orkumatskerfi fyrir jórturdýr. Við mat á þessum kerfum hefur komið í ljós að nettóorka til mjólkurmyndunar (NE_l) samkvæmt van Es og norræn fóðureining (SFU) samkvæmt Möller o.fl. gefa bestar niðurstöður þegar borin er saman áætluð og raunveruleg mjólkurframleiðsla.

Lögð er áhersla á mikla þörf fyrir orkumatskerfi fyrir jórturdýr þrátt fyrir að öll hafi þau einhverja galla. Einnig yrði það mikill ávinningur ef hægt væri að sameinast um eitt kerfi fyrir öll Evrópulönd.

Einstakir hlutar fóðursins og niðurbrotsefni munu í framtíðinni hafa meira gildi við fóðurútreikninga og fóðurgerð.

INTRODUCTION

The word **energy** originates from Greek and means “in work” (en ergon). The work of the cell is to contract itself, actively transport molecules or ions and to synthesize macromolecules from smaller molecules. The source of energy for this work is chemical energy stored in the foods consumed by animals or humans.

Energy bonds between atoms or molecules represent a potential source of energy which is released when the bond is broken.

When chemical compounds are transformed from a higher to a lower energy level, parts of their energy can then be released for useful work (free energy = ΔG) according to the following equation:

$$\Delta G = \Delta H - T\Delta S$$

where H = enthalpy (heat content in the system), T = absolute temperature, S = entropy (degree of disorganization).

The understanding of the principles for bioenergetic processes is fundamental in the science of nutrition – since all the processes that occur in the animal body when the feed is digested and metabolized leads to energy changes.

Energy is used to express the “fuel value” of feeds for animals and it comprises the three main groups of nutrients viz.:

- Carbohydrates
- Protein
- Fat

This enables us to determine quantitative relationships between the nutritional supply and the nutritional effects as a basis for the prediction of yield (production).

Today it is known that there are many factors influencing the utilization of the energy in an animal, but, provided that the requirement for **specific nutrients** such as protein, vitamins and minerals is met, the nutritional requirement is a question about energy.

ENERGY SYSTEMS

A number of feed evaluation systems have been developed over the last 200 years. It is not possible here to deal with these in detail, but the more important ones are mentioned below.

Hay unit

The hay unit was described by Albrecht von Thaer in 1809, although it is not clear who really developed the system. This was the first attempt at introducing a **replacement value**, i.e. how much of a feedstuff is needed to replace one unit of a reference feed without any change in the production.

Total digestible nutrients

Total digestible nutrients (TDN) was developed almost 150 years ago because it was shown that the proximate analyses (Weende) were not sufficient to characterize the nutritive value of feeds.

The content of TDN per kg and per kg DM of a feedstuff is calculated as follows:

TDN, kg =
kg digestible crude protein (DCP)
+ 2.25 × kg digestible ether extract (DEE)
+ kg digestible carbohydrates (DCHO)

This system has found the widest application in North America and it is still used to some extent, also in South America, Africa and Asia.

Scandinavian feed unit

The Scandinavian feed unit (SFU) originates from Denmark about 1880 where 1 kg concentrates was called a **feed unit**. The concentrate at that time was a mixture of cereals (oats and barley) but later (1915–16) the Nordic countries agreed to use **1 kg barley** as basis for the unit. Thanks to Niels Johannes Fjord and Nils Hansson the SFU was developed further and many feeding experiments were carried out to determine the replacement value for various feedstuffs.

Today the Scandinavian feed unit is estimated in the same way as Fattening feed unit (FFU), but a higher NJ_F value (14.2) is used for digestible protein (see later).

Kellner system

The Kellner system was developed nearly 100 years ago by O. Kellner and later by G. Fingerling in Germany. Because fat deposition is the “purest” form of energy retention, respiration experiments were carried out with supplements of pure nutrients (protein, fat, starch and cellulose) to adult steers. It was found that the energy (kJ) deposited as fat per gram of digestible nutrients was:

- Starch	9.87	(100)
- Straw cellulose	10.00	(101)
- Protein (gluten)	9.37	(94)
- Fat in fat rich seeds	23.85	(241)
- Fat in grain	20.92	(212)
- Fat in forages	18.83	(191)

These factors for energy deposition may be called **net joules fattening** (NJ_F), converted from Kellner’s “net calories” for fattening (1 kcal = 4.184 kJ). Relative values are given in parenthesis.

When feeds were used instead of pure nutrients, the energy values were found to be lower than those estimated by applying the factors given above. The observed value in percentage of the estimated value was called the **value number** (W=Wertigkeit):

$$W = \frac{\text{Observed value} \times 100}{\text{Estimated value}}$$

The value numbers are then used for correction of the estimated values.

For forages this correction was found to be related to the crude fiber content of the feed. This is called **fiber deduction** and based on experiments with hay and straw. Originally it was set to **5.7** NJ_F per g total crude fiber, but after the change from true protein to crude protein, a fiber deduction of 6.3 NJ_F has been used.

From the **net energy fattening** the following units are derived:

Starch equivalent (1 kg starch) = 9870 NJ_F (SE)

Fattening feed unit (1 kg barley) = 6900 NJ_F (FFU)

The problems associated with the use of a "fattening cattle" unit for other species of animals and other types of production are to a great extent overcome by use of the NJ_F-equivalents.

The main weakness of this system is the correction for the concentration of the diet. The W and the fiber deduction are rather variable and if no respiration experiment is carried out, the choice of correction factor has to be based on guesswork.

To overcome this problem, our Danish colleagues have developed a method for calculating the **cattle feed unit** (CFU) which is based on digestible energy and corrected for the content of digestible crude fiber (Møller *et al.*, 1983):

$$\text{CFU/kg DM} = -0.426 + 0.101 \text{ MJ DE} - 0.502 \text{ DCF}$$

where DE is digestible energy, MJ/kg DM, and DCF is digestible crude fiber, kg/kg DM.

It is assumed that 1 feed unit is needed per 2.5 kg of milk (7.89 MJ net energy).

Because 1 kg barley DM is estimated to equal 1.13 CFU, 1 kg of barley with 14% moisture is equivalent to 7.65 MJ net energy for lactation.

Metabolizable energy (ME) is defined as gross energy minus faecal energy, urinary energy and energy in combustible gasses (methane). ME represents the maximum amount of energy that is **available** for an animal. ME is used as measure for the energy value of feeds in Sweden since 1967 and according to Spørndly (1989) it is calculated as follows:

Forages <50% legumes:	ME=0.160x–1.91
Forages >50% legumes:	ME=0.106x–2.93
Straw:	ME=0.114x–0.47

where x is per cent organic matter degraded in rumen liquor (VOS).

For other feeds, ME (kJ per g digestible nutrient) is calculated mainly according to Axelsson (1941):

Protein	
Roughages	18.0
Concentrates	18.9
Fat	
Roughages	32.7
Cereals	34.9
Protein-concentrates	36.9
Carbohydrates	
Disaccharides	15.1
NFE	15.5
Crude fiber	12.5

The energy requirements of the animals are also given in ME without any correction for differences in utilization.

Other equations for estimating ME for ruminants are given by Schiemann *et al.* (1971) and van Es (1978).

British system

The British system (ME) was devised by Sir Kenneth Blaxter in the sixties (Blaxter, 1962; ARC, 1965 and modified by MAFF, 1975).

The energy values of feeds are expressed in terms of **metabolisable energy**.

ME can be derived at in different ways:

1. Determination in sheep.
2. Digestible organic matter data (DOM),

Table 1. Preferred values for the efficiency of utilization of metabolisable energy of normal diets by ruminants (ARC, 1980).
1. tafla. Valin gildi yfir nýtingu breytiorku í fóðri fyrir jórturdýr.

Function	Metabolizability (q_m)[a)] 0.40	0.50	0.60	0.70
Maintenance (k_m)	0.643	0.678	0.714	0.750
Growth and fattening (k_f)				
All diets	0.318	0.396	0.474	0.552
Pelleted diets	0.466	0.470	0.474	
Lactation (k_l)	0.560	0.595	0.630	0.665

a) q_m = ME/GE, $k_l = 0.35\ q_m + 0.420$, $k_f = 0.78\ q_m + 0.006$, $k_m = 0.35\ q_m + 0.503$, $k_g = 0.0435 \times$ ME/DM.

assuming that OM = 19 MJ/kg and that ME/DE = 0.81.

3. Rostock equation.
4. Prediction from chemical and *in vitro* analyses.

The energy requirements of the animals are expressed in absolute terms as net energy. The interface between the two involves calculations with a coefficient of ME utilization varying with type of production, level of intake and concentration of the diet (Table 1).

This system is considered a net energy system, because the utilization of the ME is used for estimating the requirements.

Rostock system

The Rostock system (NEF=Nettoenergie Fett) was described by Schiemann *et al.* (1971) in the book, Energetische Futter-bewertung und Energienormen.

A large number of experiments were carried out with **balanced diets** to ruminants. For cattle (Rind) the following equation was given (page 207):

$$NEF_r\ (kJ) = 7.2x_1 + 31.5x_2 + 8.4x_3 + 8.4x_4$$

where x_1–x_4 are grams of digestible crude protein, ether extract, crude fiber and N-free extracts, respectively.

Strictly, these equations are valid for concentrations (DE/GE) between 0.67–0.80 only.

For practical feeding Schiemann and coworkers proposed an **"energetical feed unit"** (Energetische Futtereinheit) which is set to 2.5 kcal (10.5 kJ) for ruminants (EF_r).

One kg of barley (14% moisture) is according to this system equivalent to 6.20 MJ NEF_r (590 EF_r).

American feed evaluation systems

The American feed evaluation systems may, apart from TDN, be divided in two principally different ones:

The California net energy system (NE_m, NE_g) as described by Lofgreen and Garrett (1968) is based on comparative slaughter experiments with sheep and beef cattle.

The net energy for maintenance and growth may be calculated as follows:

ME (Mcal/kg feed) = DE (Mcal/kg feed) × 0.82

F = g dry matter/kg $W^{0.75}$

Log F = 2.2577 – 0.2213ME

Net energy for maintenance (NE_m) = 77/F

Net energy for growth (NE_g) = 2.54 – 0.0314F

The Beltsville net energy system for lactation (NE_l) is described by NRC (1978).

The calculation of the net energy according to this system is very simple because NE_l is linearly related to the DE or ME content of the diet:

NE_l = 0.84 DE – 0.77 (Flatt, 1988)

NE_l = 0.68 DE – 0.36 (van der Honing and Alderman, 1988)

NE_l = 0.84 ME – 0.44 (Flatt, 1988)

where DE, ME and NE are all expressed as Mcal/kg DM.

The Dutch net energy lactation system

The Dutch net energy lactation system (NE_l) is described by van Es (1975 and 1978).

Based on almost all available data from energy balance experiments with dairy cows, van Es proposed a system for expressing the energy value of feeds for milk production.

From the content of ME, corrected for the concentration of the diet and the level of intake, the net energy content of the feeds is estimated.

At an energy concentration (q=100 ME/GE) of 57, a utilization of 60% is assumed. At higher and lower q the utilization is increased or decreased by 0.4 percentage unit, respectively.

The utilization of the ME is also reduced by 1.8% per multiple above maintenance (M) intake. For an average intake of 2.38 M the utilization is reduced by 2.484%.

The equation for estimation of NE_l is as follows:

$$NE_l = 0.60\,[1.0 + 0.004\,(q - 57)] \times 0.9752 \times ME$$

One feed unit milk (VEM) is equivalent to 6.9 kJ, i.e. 1 g of barley.

COMPARISON OF FEED EVALUATION SYSTEMS

Estimated values of feeds

An obvious exercise to do when comparing different feed evaluation systems is to estimate values of some feeds and see how they relate to each other.

Table 2 shows the content of ME and NE of barley with a standard composition and digestibility calculated according to different feed evaluation systems (van der Honing and Steg, 1984). According to these calculations, ME was lowest (12.6 MJ/kg DM) for the Dutch and Swiss systems (which are essentially the same) and highest for the American system (14.0 MJ/kg DM). The net energy value was lowest for EF_r followed by the NE_l (Dutch and Swiss) and highest for the Hungarian NE_l system and SFU.

Table 2. ME and NE values of barley for dairy cattle calculated using standardized composition and digestion coefficients (van der Honing and Steg, 1984).
2. tafla. Breyti- og nettóorka í byggi fyrir mjólkurkýr reiknuð út frá stöðluðu efnainnihaldi og meltanleikastuðlum.

Country/system	ME	NE
	MJ kg^{-1} DM	
Denmark/SFU		8.91
France/UFL	13.13	8.31
FRG/NE_l	13.36	8.55
GDR/EF_r	12.92	7.25
Hungary/NE_l	12.9	8.96
The Netherlands/VEM	12.65	7.76
Sweden/ME	13.44	
Switzerland/NE_l	12.62	7.76
UK/ME	13.37	
USA, Israel/NE_l	13.96	8.22
Average	13.18	8.26
SD	0.45	0.46

The absolute values of the feeds are of limited interest. Of more interest are the relative values, the replacement values.

Ekern (1982) compared fattening feed units (FFU), Dutch net energy lactation (VEM), and metabolisable energy for some common feedstuffs in Norway. Some of the results are shown in Table 3.

As one would expect the three systems compared reasonably well for concentrated feeds, but for less concentrated feeds (forages) the FFU system seemed to underestimate and the ME system to overestimate the feeding value relative to VEM. Similar calculations were made by van der Honing and Alderman (1988) showing that the estimated energy content of low quality roughages, relative to barley, was considerably lower for FFU than for other systems (Table 4).

Table 3. The energy value of some feeds expressed in FFU, VEM and ME (Ekern, 1982).
3. tafla. Orkugildi nokkurra fóðurtegunda í fitunarfóðureiningum, mjólkurfóðureiningum og breytiorku.

	DM %	Feed evaluation system FFU		VEM[a)]		ME, MJ[a)]	
		Per kg feed					
Hay, ear emerg.–flowering	85	0.48	(48)[b)]	0.63	(63)	7.6	(69)
Silage, grass, ear emerg.	22	0.16	(64)	0.19	(74)	2.3	(79)
Swedes	11	0.10	(78)	0.13	(100)	1.4	(99)
Barley grain	86	1.00	(100)	1.00	(100)	11.1	(100)
Soybean meal, extracted	88	0.94	(92)	0.97	(95)	11.0	(99)
Relative, VEM=100							
Hay		76		100		110	
Silage, grass		86		100		106	
Swedes		78		100		101	
Barley		100		100		100	
Soybean meal		97		100		103	

a) Without correction for feeding level.
b) Figures in parenthesis are relative values of 1 kg dry matter within each unit (barley=100).

Table 4. Energy values according to different feed evaluation systems relative to barley (van der Honing and Alderman, 1988).
4. tafla. Orkugildi reiknuð út frá mismunandi orkumatskerfum miðað við bygg.

	TDN USA	ME_{sw} Sweden	EF_r Rostock	FFU Finland Iceland Norway	VEM Netherlands
Grass, fresh early cut	91.1	89.4	92.2	78.8	91.1
Grass silage, unwilted	81.8	74.1	84.7	64.9	73.6
Hay, good quality	78.2	73.5	78.6	60.8	71.9
Hay, moderate quality	70.0	64.5	70.3	49.5	63.2
Barley straw	53.6	46.7	54.4	25.3	44.9
Barley grain	100.0	100.0	100.0	100.0	100.0
Wheat bran	84.9	86.0	87.6	79.8	82.4
Cane molasses	82.8	81.3	81.8	75.0	77.9
Soybean meal	100.7	109.0	92.8	98.6	101.9
Fat	251.2	260.1	412.0	286.1	313.0

For a protein-rich feed such as soybean meal ME showed the highest and FE_r the lowest relative value. The value of fat was higher according to VEM and especially according to EF_r than for the other systems.

"Observed" values of feeds

The response of the feeds in production trials should ideally be in accordance with their estimated energy values.

Based on experiments in Denmark by O. Aaes (personal communication), the predicted milk yields in four experiments (169 cows) were compared with the observed milk yields for the animals. The results are presented in Table 5.

Table 5. Observed and predicted milk yields in four Danish experiments with a total of 169 cows (Thuen, 1990).
5. tafla. Raunveruleg og áætluð nyt í fjórum dönskum tilraunum með samtals 169 kýr.

Energy system	Observed milk yield kg/d	Predicted[a)] milk yield kg/d	SD
ME	25.2	31.0	8.1
FFU	25.2	28.8	6.2
VEM	25.2	26.8	4.5

a) Predicted from total energy intake and the requirement for maintenance and weight changes.

Best correspondence between predicted and observed yield was obtained for net energy lactation (VEM) followed by FFU. Metabolisable energy gave the poorest prediction of the milk yield.

Based on five change over experiments and five continous feeding experiments with dairy cows in Finland P. Huhtanen (unpublished results) concluded that EF_r was most accurate in estimating the differences in feeding values. This was surprising because the Rostock system is based on fattening of cattle. The short duration of these experiments does not allow too wide conclusions to be drawn. As indicated before, the EF_r system seems to overestimate the value of fat which may be associated with the analytical procedure used as pointed out by M. Riis Weisbjerg (personal communication). This fact may have played a certain role in the Finnish study because many experiments included a comparison between barley and oats fed according to yield.

In a recent study, J. Berg (unpublished results) was not able to confirm the good results with EF_r in predicting the milk yields of the cows. Best fit between observed and predicted milk yield was found for SFU, corrected for feeding level, and NE_l (VEM) whereas FFU and ME gave poorer results (Table 6). Similar results were obtained by E. Thuen (personal communication).

ASSOCIATIVE EFFECTS BETWEEN FEEDS

One of the main problems in feed evaluation for ruminants is associative effects. Many studies have shown that the presupposition

Table 6. Observed milk yield (ECM), predicted milk yield, standard error of prediction corrected for live weight change (SEP(C)), energy supply as a proportion (%) of requirement (RAT), standard deviation (SD(RAT)) and coefficient of variation (CV(RAT)).
6. tafla. Raunveruleg nyt (ECM), áætluð nyt, staðalfrávik á spágildum leiðrétt fyrir breytingu í þunga á fæti (SEP(C)), aðgengileg orka sem hlutfall (%) af þörfum (RAT), staðalfrávik (SD(RAT)) og fráviksstuðull (CV(TAT)).

Feed evaluation system	No. of animals	Observed milk yield	Predicted milk yield	SEP(C)	RAT	SD(RAT)	CV(RAT)
Individual data (J. Berg, personal communication)							
FFU	835	20.8	22.5	4.6	105	12.5	12.0
SFU (corr.)	835	20.8	20.9	2.9	101	8.9	8.8
ME	835	20.8	22.8	4.5	106	11.4	10.8
NE	835	20.8	20.3	3.6	98	10.6	10.8
Treatment means (E. Thuen, personal communication)							
FFU	708	20.33	22.15	3.0	106	6.7	6.4
SFU (corr.)	708	20.33	21.43	2.3	104	6.8	6.6
ME	708	20.33	22.90	3.3	108	6.3	5.9
NE_l	708	20.33	20.27	1.8	100	5.4	5.4

Energy value for live weight change: 4.5 kg milk/kg LWC.

generally made that **energy values of feeds are additive** in many instances does not hold true. Both positive and negative associative effects between feeds may occur. The extent of interaction within diets is often hard to predict and therefore difficult to include in estimations (Mould, 1988; Bøe, 1989; P. Huhtanen, unpublished results).

FUTURE FEED ENERGY EVALUATION IN RUMINANTS

The progress in the science of ruminant nutrition over the recent years is remarkable. More sophisticated techniques have been applied, e.g. cannulation of the animal's digestive tract and better analytical procedures have been developed. Tracer kinetics, infusion techniques and arterio-venous difference measurements are other advancements made in ruminant research.

Due to these new and improved techniques the insight into the various metabolic processes, both in the digestive tract and the body proper, has expanded. The various reactions taking place can now be followed quantitatively to a much larger extent than only 30–40 years ago.

By use of modelling on computers the complicated pattern of biochemical and physical reactions in which feed components are involved can now be simulated with an increasing degree of precision. The dietary inputs may be the concentrations of soluble sugars, starch, structural carbohydrates, lipid, protein and nonprotein nitrogen and values for the rate of digestion and potential rumen degradability of structural carbohydrate and protein (Thomas, 1990).

This flow of new information has lead to the question: do we need an energy evaluation system for ruminants in the future?

For ration formulation and optimalization of diets for ruminants, there is no doubt that new systems will have to be oriented towards substrates (as it to some extent has been in the past).

For many other purposes, however, there will still be a need for an energy system by which the relative value of feeds may be expressed in a single unit. Especially for planners, economists, politicians and in trade such figures will be required. If not, feeds will be compared kg by kg, which will be a great step backwards.

REFERENCES

ARC (Agricultural Research Council), 1965. *The Nutrient Requirements of Farm Livestock, No 2. Ruminants*. Her Majesty's Stationary Office, London.

ARC (Agricultural Research Council), 1980. *The Nutrient Requirements of Ruminant Livestock*. Commonwealth Agricultural Bureaux, Slough: 351 pp.

Axelsson, J., 1941. Der Gehalt des Futters an umsetzbare Energie. *Zeitschrift für Züchtungskunde* **16**: 335–347.

Blaxter, K.L., 1962. *The Energy Metabolism of Ruminants*. Hutchinson, London: 329 pp.

Bøe, U.B., 1989. Utilization of NH_3-treated straw by sheep: Effects of supplementation with different amounts of ground barley. *Norwegian Journal of Agricultural Sciences* **3**: 329–336.

Ekern, A., 1982. Vurdering av energien i fôr til melkekyr. In: *Husdyrforsøksmøtet, NLH. Aktuelt fra Statens fagtjeneste for landbruket, Nr.* **1**: 74–79.

Flatt, W.P., 1988. Feed evaluation systems: Historical background. In: *Feed Science* (ed. E.R. Ørskov). World Animal Science, B4, Elsevier, Amsterdam: 1–22.

Lofgreen, G.P. & W.N. **Garrett**, 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. *Journal of Animal Science* **27**: 793–806.

MAFF (Ministry of Agriculture, Fisheries and Food), 1975. *Energy Allowances and Feeding Systems for Ruminants*. Technical Bulletin 33, Her Majesty's Stationary Office, London.

Møller, P.D., P.E. **Andersen**, T. **Hvelplund**, J. **Madsen** & K.V. **Thomsen**, 1983. En ny beregningsmetode for fodermidlernes energiverdi til kvæg (FE_K). *Beretning fra Statens Husdyrbrugsforsøg nr.* **55**.

Mould, F.L., 1988. Associative effects of feeds. In: *Feed Science* (ed. E.R. Ørskov). World Animal Science, B4, Elsevier, Amsterdam: 279–292.

NRC, 1978. *Nutrient Requirements of Dairy Cattle*. 5th rev. edn. National Academy of Sciences, Washington, DC.

Schiemann, R., K. **Nehring**, L. **Hoffmann**, W. **Jentsch** & A. **Chudy**, 1971. *Energetische Futterbewertung und Energienormen*. VEB Deutscher Landwirtschaftsverlag, Berlin.

Spørndly, R., 1989 (ed.). *Fodertabeller för idisslare 1989*. Sveriges lantbruksuniversitet, Uppsala. Speciella skrifter 39.

Thomas, P.C., 1990. Predicting the nutritive value of compound feeds for ruminants. In: *Feedstuff Evaluation. Proceedings of the 5th Symposium, University of Nottingham Easter School in Agricultural Sciences, July 1989* (eds J. Wiseman & D.J.A. Cole): 3011–3018.

Thuen, E., 1990. Energimål for drøvtyggere. *Informasjon fra Statens fagtjeneste for landbruket, Nr.* **16**: 20 pp.

van der Honing, Y. & G. **Alderman**, 1988. Ruminants. In: *Livestock Feed Resources and Feed Evaluation in Europe, EAAP Publication No. 37* (eds F. de Boer & H Bickel) & *Livestock Production Science* **19(1–2)**: 217–278

van der Honing, Y. & A. **Steg**, 1984. *Relationships between Energy Values of Feedstuffs Predicted with Thirteen Feed Evaluation Systems for Dairy Cows*. Report No. 160, IVVO (Institute Livestock Feeding and Nutrition Research), Lelystad, The Netherlands.

van Es, A.J.H., 1975. Feed evaluation for dairy cows. *Livestock Production Science* **2**: 95–107.

van Es, A.J.H., 1978. Feed evaluation for ruminants. I. The systems in use from May 1977 onwards in The Netherlands. *Livestock Production Science* **5**: 331–345.

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