EVALUATION OF THE NEL SYSTEM AND ESTIMATION OF ENERGY REQUIREMENTS FOR DAIRY COWS ON THE BASIS OF AN EXTENSIVE DATA SET FROM FEEDING TRIALS

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ABSTRACT

The maintenance requirements of dairy cows are assumed to be about 0.293 – 0.350 MJ NEL/kg $LW^{0.75}$ in most of the recent energy systems established in Europe and USA. The utilisation of ME for milk production (k_l) is in the range of 0.60 – 0.63 in these systems. Recent research results from Northern Ireland indicate both a higher maintenance requirement and a higher energetic efficiency for milk production.

A comprehensive data set obtained from long term feeding experiments with lactating dairy cows carried out in 9 research institutes of Germany, Austria and Switzerland was used to evaluate the current German feeding standards (GfE 2001). The NEL system was validated by regressing the NEL requirements calculated on the basis of its assumptions on the actual NEL intakes (MJ). ME requirements were estimated using multiple regression analysis with $LW^{0.75}$ (live weight), LE (lactation energy), and LWC (live weight change) as independent variables.

The validation of the NEL system is described by the following equation and shows high individual deviations from the regression line, leading to low R^2:

NE requirement calculated = 24.1 + 0.83 × NE intake (1)

R^2 = 0.660, MSPE = 316, MPE = 17.8 MJ NEL and 14.7 %, respectively.

Components of MSPE: Bias = 3.7%, Line = 10.9%, Random = 85.4%.

The estimation of the ME requirement is described by the following equation:

ME intake = 0.652 × $LW^{0.75}$ + 1.41 × LE + 16.6 × LWC (2)

R^2 = 0.717, RSD = 24.1 MJ

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The results reveal a considerable higher maintenance energy requirement than used in current energy systems, but are in line with recent observations in experiments carried out in Northern Ireland; the coefficient of energetic efficiency for lactation is higher than in current systems (k_l = 1/1.41 = 0.71) as well. The higher k_l value could be due to an increased proportion of ruminally undegraded nutrients in actual feed rations resulting in decreased microbial fermentation losses and a relatively lower chewing activity in low forage diets. The equation gives a much lower energy content for mobilisation/retention of body reserves (E_{LWC} = 16.6 × 0.71 = 11.8 MJ) than usually expected. Besides, the relationship between LWC and energy balance is not significant. Actually, LWC cannot be regarded as a useful predictor of energy balance. Both an increased internal organ mass associated with higher feed intake and a higher protein content (lower BCS) of high yielding dairy cows could be possible reasons for the enhanced maintenance energy requirement. It is concluded that recent data from feeding trials provide evidence that current NE systems for lactating dairy cows underestimate the energy requirement for maintenance and overestimate the energy requirement for lactation.

BEWERTUNG DES NEL-SYSTEMS UND SCHÄTZUNG DES ENERGIEBEDARFS VON MILCHKÜHEN AUF DER BASIS EINES UMFANGREICHEN DATENMATERIALS AUS FÜTTERUNGSVERSUCHEN IN DEUTSCHLAND, ÖSTERREICH UND DER SCHWEIZ

AUSZUG

Der Erhaltungsbedarf an Energie für Milchkühe ist in den derzeit verwendeten Energiesystemen in Europa und den USA mit etwa 0.293 – 0.350 MJ NEL/kg $LM^{0.75}$ festgelegt. Die Verwertung der ME für die Milch Produktion (k_l) liegt in diesen Systemen im Bereich von 0.60 – 0.63. Aktuelle Forschungsergebnisse in Nordirland weisen auf einen höheren Erhaltungsbedarf und auf eine höhere Effizienz der Energieverwertung für die Milchproduktion hin.

Es wurden umfangreiche Daten aus langfristigen Fütterungsversuchen mit Milchkühen in 9 Forschungsinstituten Deutschlands, Österreichs und der Schweiz herangezogen, um das zur Zeit in Deutschland verwendete NEL-System zu validieren (GfE 2001). Die Validierung erfolgte durch eine Regression zwischen NEL-Bedarf (errechnet nach GfE 2001) und tatsächlicher NEL-Aufnahme (MJ). Der ME-Bedarf wurde über eine multiple Regression mit $LM^{0.75}$ (Lebendmasse), LE (Milchenergie) und LMV (Lebendmasse-Veränderung) als unabhängigen Variablen geschätzt.

Die Validierung des NEL-Systems wird durch folgende Gleichung beschrieben und zeigt hohe individuelle Abweichungen der Tiere von der Regressionsgeraden, verbunden mit einem niedrigen R^2:

$$\text{NEL-Bedarf (berechnet)} = 24.1 + 0.83 \times \text{NEL-Aufnahme} \quad (1)$$

R^2 = 0.660, MSPE = 316, MPE = 17.8 MJ NEL bzw. 14.7 %

Aufteilung des MSPE: Systemat. Abweichung = 3.7 %, Linie = 10.9 %, Zufall = 85.4 %.

Die Schätzung des ME-Bedarfs wird durch folgende Gleichung beschrieben:

$$\text{ME-Aufnahme} = 0.652 \times LM^{0.75} + 1.41 \times LE + 16.6 \times LMV \quad (2)$$

R^2 = 0.717, RSD = 24.1 MJ

Die Ergebnisse weisen auf einen deutlich höheren Energie-Erhaltungsbedarfs hin, als er in den gängigen Bewertungssystemen angenommen wird, decken sich jedoch mit aktuellen Forschungsergebnissen in Nordirland; auch der Verwertungskoeffizient für Laktation ist höher als derzeit festgelegt (k_l = 1/1.41 = 0.71). Der höhere k_l-Wert könnte in einem gestiegenen Anteil von im Pansen nicht abgebauten Nährstoffen in heutigen Milchvieh-rationen begründet sein, die zu geringeren mikrobiellen Fermentationsverlusten und zu einem geringeren Kauaufwand in Rationen mit geringem Grundfutteranteil führen. Die Gleichung ergibt einen wesentlich geringeren Wert für die Mobilisation/Retention von Körperreserven (E_{LMV} = 16.6 × 0.71 = 11.8 MJ) als üblicher Weise erwartet. Die Beziehung zwischen LMV und Energiebilanz ist nicht signifikant. Daher kann die LMV nicht als geeigneter Parameter zur Beschreibung der Energiebilanz bezeichnet werden. Sowohl der höhere Anteil innerer Organe, der mit erhöhter Futteraufnahme einhergeht, als auch der höhere Proteingehalt (geringerer BCS) von hoch leistenden Milchkühen können mögliche Gründe für einen gestiegenen Erhaltungsbedarf an Energie sein. Die aktuellen Daten aus Fütterungsversuchen lassen den Schluss zu, dass die gängigen NEL-Systeme für laktierende Milchkühe den Erhaltungsbedarf an Energie unterschätzen und den Bedarf für die Laktation überschätzen.

1. INTRODUCTION

The maintenance requirements of dairy cows are assumed to be about 0.293 – 0.350 MJ NEL/kg $LW^{0.75}$ in most of the recent energy systems established in Europe and USA (INRA 1989, AFRC 1993, GfE 2001, NRC 2001). The utilisation of ME for milk production (k_l) is in the range of 0.60 – 0.63 in these systems. Recent research results from Northern Ireland indicate both a higher maintenance requirement and a higher energetic efficiency (i.e. lower requirement) for milk production (Agnew & Yan 2000, Agnew et al. 2003). In the present work extensive data from feeding trials (Gruber et al. 2005) are used to evaluate the current NE system in Germany and estimate energy requirements for dairy cows.

2. MATERIAL AND METHODS

A comprehensive data set (n = 24,583; means of two lactation weeks of individual cow measurements) obtained from long term feeding experiments with lactating dairy cows carried out in 9 research institutes of Germany, Austria and Switzerland (Gruber et al. 2005) was used to evaluate the current German feeding standards (GfE 2001). The experiments were carried out with Simmental, Brown Swiss and Holstein Friesian cows and the data showed a wide variation both in animal parameters [(mean, SD, range); DIM (138 ± 78, 2 – 459), milk yield (24.3 ± 8.1, 2.2 – 60.6 kg/d), DM intake (18.5 ± 3.5, 5.4 – 31.6 kg DM/d)] as well as nutritional factors [NEL content (5.9 ± 0.5, 4.1 – 7.4 MJ/kg DM), proportion of concentrate in the diet (25.6 ± 17.9, 0.0 – 81.1 % of DMI)]. The NEL system was validated by regressing the NEL requirements calculated on the basis of its assumptions [0.293 MJ NEL/kg $LW^{0.75}$ for maintenance, NE in milk = 0.38 × fat + 0.21 × protein + 0.95 (Tyrrell & Reid 1965), 25.5 MJ NEL for gain and 20.5 MJ NEL for loss of 1 kg LW, NEL pregnancy = (0.044 × exp(0.0165 × day of gestation/0.175 × 0.6)] on the actual NEL intakes (MJ). ME requirements were estimated using multiple regression analysis with $LW^{0.75}$, LE and LWC as independent variables.

3. RESULTS AND DISCUSSION

3.1. Evaluation of the NEL system

The results of the validation of the NEL system are shown in equation (1) and Fig. 1:

NE requirement calculated = 24.1 + 0.83 × NE intake (1)

R^2 = 0.660, MSPE = 316, MPE = 17.8 MJ NEL and 14.7 %, respectively.

Components of MSPE: Bias = 3.7%, Line = 10.9%, Random = 85.4%.

This regression equation shows a bias of 3.7% of MSPE (mean NE requirement = 124.5 MJ, mean NE intake = 121.1 MJ) and an even higher error caused by a systematic deviation of the regression line from 1 (x = y), the slope = 0.83 and intercept = 24.1, despite a high prediction error (MPE = 17.8 MJ NEL or 14.7% of NEL intake).

3.2. Estimation of energy requirements for dairy cows

In order to find reasons for the relatively low correlation, a multiple regression analysis was carried out relating ME intake (MJ) on metabolic live weight ($LW^{0.75}$, kg), milk energy output (LE, MJ/d) and live weight change (LWC, kg/d). Requirement for pregnancy was fixed as specified by GfE (2001) and subtracted from total ME intake (MJ ME/d):

$$\text{ME intake} = 0.652 \times LW^{0.75} + 1.41 \times LE + 16.6 \times LWC \quad (2)$$

R^2 = 0.717, RSD = 24.1 MJ

The results reveal a considerable higher maintenance energy requirement than used in current energy systems (INRA 1989, AFRC 1993, GfE 2001, NRC 2001), but are in line with recent observations in experiments carried out in Northern Ireland (0.600 – 0.660 MJ ME/kg $LW^{0.75}$; Agnew & Yan 2000, Agnew et al. 2003, FiM 2004); the coefficient of energetic efficiency for lactation is higher than in current systems (k_l = 1/1.41 = 0.71) as well. Agnew & Yan (2000) and Agnew et al. (2003) reported values of k_l = 0.64 – 0.69, based on literature data since 1976 and own experimental results. The higher k_l value could be due to an increased proportion of ruminally undegraded nutrients in actual feed rations resulting in decreased microbial fermentation losses and a relatively lower chewing activity (Susenbeth et al. 2004) in low forage diets. The equation gives a much lower energy content for mobilisation/retention of body reserves (E_{LWC} = 16.6 × 0.71 = 11.8 MJ) than usually expected. Besides, the relationship between LWC and energy balance is not significant (Fig. 2). Actually, LWC cannot be regarded as a useful predictor of energy balance. In their review, Agnew & Yan (2000) concluded that a fixed energy value for LWC as used in NRC and European systems is incorrect since it varies with body condition (BCS) and change of lactation (Tamminga et al. 1997). Unfortunately, BCS is not available in these data. Agnew & Yan (2000) discuss that both an increased internal organ mass associated with higher feed intake and a higher protein content (lower BCS) of high yielding dairy cows are possible reasons for the enhanced maintenance energy requirement. This is supported by the present results when considering an interaction term of [live weight × milk yield] in the following equation:

$$\text{IME} = (0.637 + (0.0088 \times \text{milk yield})) \times LW^{0.75} + 1.09 \times LE + 16.7 \times LWC \quad (3)$$

R^2 = 0.722, RSD = 23.8 MJ

It is concluded that recent data from feeding trials provide evidence that current NE systems for lactating dairy cows underestimate the energy requirement for maintenance and overestimate the energy requirement for lactation, leading to higher total requirements at lower yields and decreased total requirements at high yields (> 30 kg). This would facilitate formulating diets for high yielding animals.

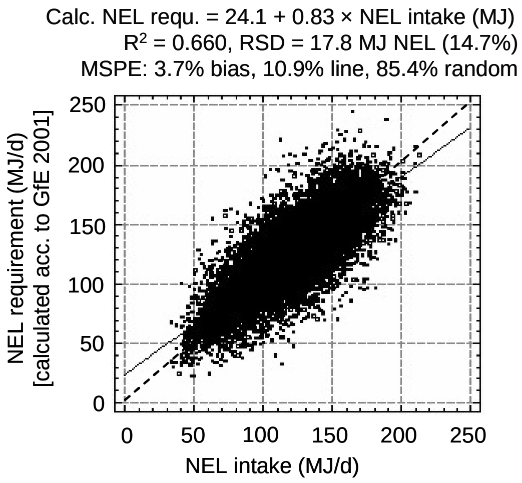

Fig. 1: Observed NEL intake and calculated NEL requirement (based on GfE 2001)

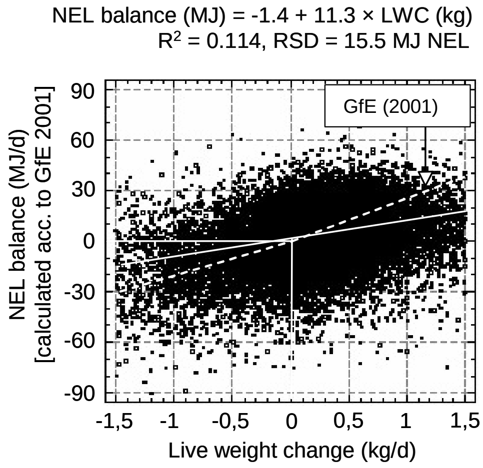

Fig. 2: Observed live weight change and calculated NEL balance

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