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Influence of Nutrition Level on Digestibility in High Yielding Cows and Effects on Energy Evaluation Systems

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ABSTRACT

The objective of the study was to determine the effect of nutrition level (NL, multiples of maintenance energy requirement) on the digestibility of nutrients for dairy cows regarding the energy supply of the animal. The digestion of nutrients and energy was investigated in two trials using lactating dairy cows. The NL varied from 2.7 to 5.0 using diets similar composition. In addition, sheep were given the same feed with a NL of 1.4. Digestibility of dry matter (DM) and all specific measures of dietary components declined significantly as NL increased. Digestibility of energy decreased by 4.1% for each increase in NL. The metabolizable energy, the ability to metabolize energy (metabolizable energy/gross energy), and the content of net energy for lactation (NE_L) per kilogram of DM intake were calculated for NL from 1 to 6 on the basis of these relationships and as well as the gross energy, methane energy, and urine energy. Accordingly the NE_L content declined by 0.11 MJ/kg of DM intake or 1.6% as the NL increased by one unit. It means that the NE_L requirement above the maintenance requirement increased by 0.07 MJ of NE_L per kilogram of fat-corrected milk, if the NL increased by one unit.
(**Key words:** digestibility, nutrition level, net energy for lactation)

Abbreviation key: EE = ether extract, **GE** = gross energy, **ME** = metabolizable energy, **NL** = nutrition level.

INTRODUCTION

The energy concentration of different feeds is calculated on the basis of chemical composition and digestibility of nutrients; thereby the digestibility coefficients are determined in sheep given diets for maintenance (Schiemann, 1981). With the increasing performance of the dairy cow, feed intake rises but digestibility coefficients of nutrients and energy decrease (Brown, 1966; Schiemann et al., 1970; Colucci et al., 1982). The problem of decreasing digestibility of energy with rising nutrition level (**NL**, defined as the multiple of maintenance or total metabolizable energy [**ME**]/ME for maintenance) and the associated compensation of energy losses by concomitant reduction of the excretion of methane and urine (Schiemann et al., 1970, 1971) has been not extensively discussed. Different feed evaluation systems consider the incomplete compensation of energy loss by the decrease of digestibility with rising NL in different ways. In the German and English systems, the compensation results from an increment of the values of energy requirement by, respectively, 0.8% (GfE, 2001) and by 1.8% (AFRC, 1993) per NL above 1. In the American system (NRC, 2001) the compensation is implemented by altering the energetic feed value of the particular feeds. On average, a reduction of 8% of the tabulated value of total digestible nutrients at average production levels is considered, which comprise the NL 2 to 4 (average NL = 3). The energy contents of feedstuffs are specified for the three and four times maintenance intake, whereas no data are available for NL higher than 4.

Balance studies on dairy cows were described until a NL of 3 to 3.5 (Schiemann et al., 1970, 1971), respectively, a NL of 4 (Ekern, 1972). However, the current performance of dairy cows on NL 5 to 6 has to be considered. Research is needed to define the digestibility of nutrients of diets for high-yielding dairy cows. Our objectives were to determine the influence of NL on digestibility of diets and to discuss the consequences for calculation of energy requirement in high-yielding dairy cows.

MATERIALS AND METHODS

Experimental Design

The influence of the NL on the digestibility of nutrients was examined in two experiments using two almost identical feed rations (Tables 1 and 2).

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Table 1. Animals and DMI (mean ± SD) used in experiments.

	Nutritional level[1]		
Item	1 to 1.5	2.5 to 3.0	4.5 to 5.0
Animals	Sheep (n = 4)	Dairy cows (n = 4)	Dairy cows (n = 4)
Experiment 1			
BW, kg	36.9 ± 1.5	709 ± 69	623 ± 64
DIM		214 ± 25	74 ± 16
DMI, kg/d	0.807	14.92 ± 0.08	25.51 ± 0.98
FCM, kg/d		23.4 ± 2.9	47.7 ± 3.8
Experiment 2			
BW, kg	37.2 ± 1.5	704 ± 69	618 ± 62
DIM		230 ± 25	90 ± 16
DMI, kg/d	0.796	14.74 ± 0.05	24.12 ± 0.02
FCM, kg/d		20.1 ± 2.9	45.0 ± 2.4

[1]NL = Multiples of maintenance energy requirement.

Animals

The experiments with medium and high NL were done with dairy cows. Because the study with low NL was not suitable for lactating cows, wethers were used for it. The agreement between sheep and cattle regarding nutrient digestibility at NL 1 to 1.5 was demonstrated by Schiemann et al. (1968) and Jentsch et al. (1993).

Wethers. Eight German Blackheaded Mutton sheep-wethers with a BW of 36 to 39 kg were used for the investigations at NL 1 to 1.5 (Table 1). All wethers were dewormed before the beginning of the trials. The animals were housed individually in metabolism cages (105 × 60 cm) in a metabolic house at 18 to 20°C to allow measurement of feed intake.

Dairy cows. Eight cows in the second and third lactation were used. Animal data are shown in Table 1. All animals were kept in individual feeding stalls at 18 to 21°C. The cows were milked three times daily (0400, 1200, and 1900 h) in a dairy parlor with a bucket milker. Milk production was recorded at each milking. Average daily milk performance amounted to 46.4 kg of FCM per cow with the NL 4.5 to 5.0 and 21.8 kg of FCM per cow with the NL 2.5 to 3.0.

Table 2. Composition of the rations used in experiments 1 and 2.

Item	Experiment 1	Experiment 2
Ingredients, % of DM		
Corn silage, chopped, 5 mm	50.4[1]	49.7[2]
Wilted grass silage, chopped, 20–40 mm	16.5	16.7
Corn grain[3], grounded, 4 mm	7.7	7.7
Protein-rich concentrate[4]	21.0	21.3
Palm fat rumen protected[5]	1.6	1.7
Mix of minerals and active ingredients[6]	2.8	2.9
Chemical composition, g/kg DM		
CP	161	167
Crude fiber	159	159
Ether extract	49	49
N-free extract	551	547
Starch	215	183
NDF	344	332
ADF	192	192

[1]Variety of corn silage was Lenz.

[2]Variety of corn silage was Citi.

[3]71% DM, treaded with lactic acid bacteria, 3×10^5 cfu/g (BIOSIL, Dr. Pieper Ltd., Wuthenow, Germany).

[4]Soybean meal (extracted) and rapeseed meal (extracted).

[5]Produced from palm oil contained 85% C16:0 + C18:0, melting point 59°C (Bergafett T-300, Berg & Schmidt Ltd., Hamburg, Germany).

[6]Contained 29% propylene glycol (1.2 Propandiol USP, Bayer Chemie Ltd., Köln, Germany), 0.22% $NaHCO_3$, 8% niacin, and 41% mineral and vitamin mix (D-Lactal, Spezialfutter Ltd., Neuruppin, Germany that contained 21% Ca, 4% P, 8% Na, 5% Mg, 0.1% Cu, 0.6% Zn, 0.35% Mn, 0.0021% Co, 0.1% I, 0.003% Se, 1000 IU/g of vitamin A, 125. IU/g of vitamin D_3, and 17 IU/g of vitamin E.

Diets. The ingredients and chemical parameter of diets are shown in Table 2.

Feeding

Wethers. After an adaptation period, a 14-d preliminary period was conducted feeding the respective experimental ration. To ensure the same ration composition for both wethers and cows, the rations for wethers (about DMI 21 g/kg of BW) were prepared (single for each animal and each daily meal in closed polyethylene bag) together with the rations for cows and stored frozen (–18°C) until the beginning of the trials. The frozen portions were thawed 24 h before feeding in closed bag at 18 to 20°C. The daily diet was given in equal amounts at 0700 and 1600 h. The diets were consumed completely by the animals. As shown by Beever et al. (1976) no influence of freezing and thawing procedures on digestibility is to be expected.

Dairy cows. Even though the cows were adapted to the ration, a preliminary period of 10 d was maintained. In experiment 1, at the high NL (5), cows were fed ad libitum individually, allowing for 10% orts. At NL 3 and in experiment 2, cows were restricted fed. The animals were fed twice daily (0700 and 1700 h). The roughage (weighing precision ±1 g) and feed supplements (weighing precision ±0.1 g) were intensively mixed by hand before feeding. Remaining feed residues (experiment 1, NL 5) were recorded daily and considered quantitatively for calculation of nutrient intake.

Sampling and Sample Processing

Feedstuffs. Samples of the feedstuffs were taken daily before mixing the rations. The samples were stored at –18°C and composited at the end of the experiment to obtain an average sample. Silage samples were freeze-dried. Concentrate samples were dried at 65°C in an oven with constant airflow. The dried samples were ground over a 1-mm screen, air equilibrated, and stored until analysis.

Feces. The length of the collection was 7 d for wethers and 6 d for cows. The feces of the wethers were collected in special collection bags fixed on the animals with leather straps. Urine was not collected. The collection bags were emptied twice daily at feeding time. The daily collected feces per animal were stored at 0°C and mixed at the end of the experiment. Subsamples of mixed feces were used for DM determination and drying at 65°C in an oven with constant airflow. The dried feces was ground through a laboratory mill with a 1-mm sieve, air equilibrated, and stored until analysis.

Quantitative collection of feces in cows was manually done around-the-clock with buckets. Every single fecal sample was weighed (weighing precision ±1 g) and homogenized before an aliquot of 2% was taken to obtain a pooled sample. The pooled sample of feces was stored at –18°C and used for DM determination and freeze-drying. The dried samples were treated like the fecal samples from wethers.

Analytical Methods

Duplicate analyses were conducted for all estimated nutrients. Generally, the Weende feed analysis method (Naumann and Bassler, 1993) was applied. Determination of CP was conducted in samples of feed as well as in samples of feces by combustion analysis by Dumas using the equipment “elementar macro N” (Elementar Analysensysteme, Hanau, Germany). The ether extract (**EE**) determination was conducted with HCl-hydrolysis according to Kuhla et al. (1983). Starch content was determined by the method of Zwierz et al. (1981) using starch digestion by a thermostable amylase and anthrone sulfuric acid as indicator reagent. Both NDF and ADF were determined according to Goering and Van Soest (1970).

Calculation of Energy Content

The gross energy (**GE**) in feed was calculated by following equation:

$$\text{GE (MJ)} = 0.0239 \times \text{CP(g)} + 0.0398 \times \text{EE(g)} + 0.0201 \times \text{CF(g)} + 0.0175 \times \text{NFE(g)} \text{ (GfE, 2001)}$$

where CF = crude fiber, NFE = nitrogen-free extract, and digestible energy (DE) was calculated using the digestible (d) nutrients as follows (Hoffmann and Schiemann, 1980):

Cattle:

$$\text{DE (MJ)} = 0.0242 \times \text{dCP(g)} + 0.0341 \times \text{dEE(g)} + 0.0185 \times \text{dCF(g)} + 0.0170 \times \text{dNFE(g)}$$

Sheep:

$$\text{DE (MJ)} = 0.0239 \times \text{dCP(g)} + 0.0379 \times \text{dEE(g)} + 0.0183 \times \text{dCF(g)} + 0.0170 \times \text{dNFE(g)}.$$

The following equations were used to calculate the urinary and methane energy:

$$\text{Urinary energy (\% of GE)} = 6.41 - 0.98 \times \text{NL}$$
(Schiemann et al., 1970)

$$\text{Methane energy (\% of GE)} = 11.26 - 1.28 \times \text{NL}$$
(Schiemann et al., 1970)

Table 3. Digestibility of nutrients (%) in experiment 1 (means ± SD; n = 8).

Item	NL = 5.0[1]	NL = 2.8[1]	NL = 1.4[2]
DM	64.6[a] ± 1.3	70.0[b] ± 0.9	76.1[c] ± 1.4
OM	66.2[a] ± 1.2	72.3[b] ± 0.9	79.0[c] ± 1.7
CP	63.1[a] ± 2.5	67.7[b] ± 2.0	77.0[c] ± 2.8
Crude fiber	53.3[a] ± 2.0	65.6[b] ± 1.1	71.4[c] ± 2.5
Ether extract	57.4[a] ± 1.5	62.2[a] ± 3.2	68.7[b] ± 2.1
Starch	88.6[a] ± 0.8	90.8[b] ± 1.2	98.9[c] ± 0.5
NFE	71.5[a] ± 0.8	76.4[b] ± 0.9	82.7[c] ± 2.3
NDF	48.3[a] ± 1.8	59.0[b] ± 1.1	68.7[c] ± 3.0
ADF	48.8[a] ± 2.7	59.6[b] ± 0.8	68.5[c] ± 2.9
Energy	62.8[a] ± 1.3	68.7[b] ± 1.0	75.8[c] ± 1.5

[a,b,c]Different letters within a row show significant differences ($P < 0.05$).

[1]Dairy cows. NL = nutrition level.

[2]Wethers.

Statistical Treatment

Calculation of digestibility parameters, arithmetic means, and their variance were conducted with the software package Excel 7.0 (Microsoft Corporation, Redmond, CA). Linear regression analysis and LSD test for tests of significance were performed with the software package SPSS 10.0 (SPSS Inc., Chicago, IL). Significant differences ($P < 0.05$) were indicated with different letters within a row.

RESULTS

Results of digestibility of nutrients obtained in experiment 1 are shown in Table 3. As expected, digestibility of the respective nutrient variable differs distinctly between the NL. These differences are significant ($P < 0.05$), except for EE between NL 2.8 and 5.0.

Results of experiment 1 were generally verified by the findings of experiment 2 (Table 4). Differences shown in Table 4 are significant, except for digestibility of crude fiber, EE, and ADF between NL 1.4 and 2.7.

The results of the regression analysis of the dependence of digestibility on the NL is of importance and can be seen in Table 5. Given relationships vary ($P < 0.05$) for all nutrients and energy. Regression coefficients for particular nutrients and energy show the varying degree of the negative effect of the NL on their digestibility. This tends to result in the following order:

NDF > ADF > CF > CP > energy > OM > DM > NFE > EE > starch.

DISCUSSION

According to the investigations of Brown (1966), Schiemann et al. (1971), and Colucci et al. (1982), the ration composition has a wide influence on the effect of NL on digestibility of both nutrients and energy. Therefore, the presented results were obtained with almost the same composition of the ration.

The results of our investigation (Tables 3 to 5) verify the relationship between digestibility of nutrients and of energy and the NL. The rate of depression in digestibility of energy amounted to 3.2 units, or 4.1%, for each increase in NL. In a review, Tyrrell and Moe (1975) found a value of about 4% for total digestible nutrients. Finger et al. (1998) recently published similar findings

Table 4. Digestibility of nutrients (%) in experiment 2 (means ± SD; n = 8).

Item	NL = 4.6[1]	NL = 2.7[1]	NL = 1.4[2]
DM	67.2[a] ± 1.2	72.3[b] ± 1.1	74.8[c] ± 0.4
OM	69.0[a] ± 1.2	74.5[b] ± 1.0	77.5[c] ± 0.4
CP	66.3[a] ± 1.3	71.5[b] ± 2.2	78.3[c] ± 2.7
Crude fiber	57.4[a] ± 1.9	66.7[b] ± 1.2	68.9[b] ± 1.1
Ether extract	61.7[a] ± 0.6	64.3[b] ± 1.6	67.4[b] ± 2.6
Starch	91.1[a] ± 2.0	94.5[b] ± 1.3	98.7[c] ± 0.6
N-free extract	74.1[a] ± 1.3	78.6[b] ± 0.9	80.6[c] ± 1.0
NDF	52.9[a] ± 1.2	61.9[b] ± 1.1	65.3[c] ± 0.9
ADF	54.9[a] ± 0.6	63.6[b] ± 2.3	65.2[b] ± 0.5
Energy	65.4[a] ± 1.4	70.6[b] ± 1.0	74.1[c] ± 0.4

[a,b,c]Different letters within a row show significant differences ($P < 0.05$).

[1]Dairy cows. NL = nutrition level.

[2]Wethers.

Table 5. Regression equations for dependence of digestibility of nutrients and energy (%) on the nutrition level (measure range 1.4 to 5).

Nutrient/energy	Equation	Variance	Coefficient of determination
DM	= 79.36 – 2.85 × NL	± 1.36	0.90 (1)
OM	= 82.60 – 3.18 × NL	± 1.42	0.92 (2)
CP	= 81.95 – 3.77 × NL	± 2.47	0.83 (3)
Ether extract	= 71.26 – 2.58 × NL	± 2.34	0.72 (4)
Crude fiber	= 77.53 – 4.54 × NL	± 2.07	0.91 (5)
N-Free extract	= 85.23 – 2.64 × NL	± 1.56	0.86 (6)
Starch	= 101.31 – 2.55 × NL	± 1.99	0.78 (7)
NDF	= 74.20 – 4.95 × NL	± 2.34	0.91 (8)
ADF	= 73.94 – 4.62 × NL	± 2.90	0.85 (9)
Energy	= 79.15 – 3.21 × NL	± 1.39	0.92 (10)

on the influence of increasing DMI of rations with identical composition but with or without the addition of partially protected fat on digestibility of nutrients and energy. In their study, the energy content decreased from 6.9 to 6.3 MJ of NE_L/kg of DMI as level of DMI increased from 8.4 to 21.0 kg/d per cow.

Utilizing the GE, urine energy, methane energy, and the equations [2] and [10] in Table 5 it is possible to calculate the energetic feed value for a ration with a composition according to experiment 1 and 2 (Table 2) at different NL (Table 6). Nevertheless, it has to be considered that the equations of urine energy and methane energy (Schiemann et al., 1970) experimentally represent the measured range of NL only from 1 to 3.5. Data for NL 4, 5, and 6 are extrapolated due to the lack of data regarding these NL.

Metabolizable energy declines from 11.21 MJ/kg DM at NL 1 to 10.48 MJ/kg DM at NL 6 (–0.15 MJ of ME/kg DM per NL; Table 6). The net energy content decreases from 6.81 MJ/kg DM at NL 1 to 6.27 MJ/kg DM at NL 6 (–0.11 MJ of NE_L/kg DM or –1.6% per NL). This value corresponds to the correction value of 1.8% per NL used by the AFRC (1993).

In NRC (2001), which considers the effect of the decline of digestibility on the NE_L content of the respective feedstuff, this correction value depends on the total digestible nutrients content of the feed. Thus, it rises with increasing total digestible nutrients content. For energy-rich feedstuffs, which are specifically fed to high-yielding dairy cows, this correction value amounts to 4.5 to 5.5% between the NL 3 and 4.

An isolated comparison of the consideration of the remaining energetic impact of declining digestibility at rising NL in the different feed evaluation systems is complicated, because this impact has to be considered in context with the deduced and defined values for feed value as well as requirements of animals in the respective feed evaluation systems. This becomes particularly obvious in the review of Vermorel and Coulon (1998). The authors conclude that the ME and NE_L values of feeds seemed overestimated by the United States system (NRC, 2001) compared with results using the Euro-

Table 6. Calculation of metabolizable energy (ME) and NE_L content (MJ/kg DM) of the experimental diets depending on the nutrition level.

Item	Nutrition level					
	1	2	3	4	5	6[1]
Digestibility of OM, %	79.3	76.2	73.0	69.9	66.7	63.6
Digestibility of energy, %	75.5	72.5	69.4	66.4	63.3	60.3
Gross energy (GE), MJ/kg DM	18.65	18.65	18.65	18.65	18.65	18.65
Methane energy, % of GE	9.98	8.70	7.42	6.14	4.86	3.58
Urinary energy, % of GE	5.43	4.45	3.47	2.49	1.51	0.53
Methane energy, MJ/kg DM	1.86	1.62	1.38	1.15	0.91	0.67
Urine energy, MJ/kg DM	1.01	0.83	0.65	0.46	0.28	0.10
Digestible energy (DE), MJ/kg DM	14.08	13.51	12.95	12.38	11.81	11.25
ME, MJ/kg DM[2]	11.21	11.06	10.92	10.77	10.62	10.48
q = (ME/GE) × 100	60.1	59.3	58.5	57.7	57.0	56.2
NE_L, MJ/kg DM[3]	6.81	6.70	6.59	6.48	6.37	6.27

[1]Values for NL 6 were extrapolated, because no experimental data are available.

[2]ME (MJ/kg DM) = DE (MJ/kg DM) – (methane energy [MJ/kg DM] + urinary energy [MJ/kg DM]).

[3]NE_L (MJ) = 0.6 (1 + 0.004 [q – 57]) × ME (MJ).

Table 7. Calculation of milk production and NE_L consumption for milk production depending on the energy concentration calculated for the nutrition levels 1 to 6.[1]

	Nutrition level					
Item	1	2	3	4	5	6
NE_L, MJ/kg DM	6.81	6.70	6.59	6.48	6.37	6.27
NE_L, MJ at 25 kg DMI	170.2	167.5	164.7	162.0	159.3	156.8
NE_L, MJ for maintenance	37.7	37.7	37.7	37.7	37.7	37.7
NE_L, MJ for milk production	132.5	129.8	127.0	124.3	121.6	119.1
Milk yield kg/d, 3.14 MJ/kg[2]	42.2	41.3	40.4	39.6	38.7	37.9
Conclusion for German system (GfE,2001):						
NE_L per kg milk based on NE_L intake at NL = 1, MJ	3.14	3.21	3.28	3.35	3.42	3.49
DMI for 40 kg FCM, kg/d	24.0	24.4	24.8	25.2	25.6	26.0

[1]For explanation see text. Values for NL 6 were extrapolated, because no experimental data are available.

[2]4.0% fat, 3.2% protein; MJ/kg Milk = 0.38 × % fat + 0.21 × % protein + 0.95 (Tyrrell and Reid, 1965).

pean systems; however, the ratio of NE_L to TDN was almost constant. As a consequence, the feed requirements were generally lower in the NRC system than in European systems, especially for higher milk production.

Transforming the reduction of digestibility by the NL as determined in the presented investigations onto a "standard cow" (650 kg of BW and 37.7 MJ maintenance requirement with 4.0% fat and 3.2% protein in milk) and calculating the milk formation capability, results in feed energy content for milk yields as shown in Table 7.

Feeding a ration with energy of 6.81 MJ of NE_L/kg DM (determined at NL 1) and a DMI of 25 kg, a milk yield from feed energy of 42.2 kg would be expected, without consideration of the remaining energetic impact. Considering the remaining energetic impact, dietary milk yield potential decreases to 37.9 kg at NL 6 (−4.3 kg of milk total, or 0.9 kg of milk per NL). Thereby the NE_L requirement increases above the maintenance requirement from 3.14 MJ of NE_L/kg of FCM at NL 1 to 3.49 MJ of NE_L/kg of FCM at NL 6 (0.07 MJ per NL).

It is obvious that the energetic feed value of a ration, or the energy requirement per kilogram of milk, clearly depends on the respective NL, and that this has to be considered up to NL 6. Whether this is considered on the level of feed value or on the level of energy requirement per kilogram of FCM, has to be decided by useful reasons.

The GfE (2001) considers this impact on the level of requirement fixing per kilogram of milk. A requirement of 3.3 MJ of NE_L/kg of ECM is deduced and defined for milk yields between 30 and 40 kg/d. This specification results from additional expenses of 0.8% per NL, which was calculated with 0.086 MJ/kg of FCM for 30 kg of FCM and with 0.106 MJ/kg of FCM for 40 kg of FCM. Thus, the fixed requirement of 3.3 MJ of NE_L/kg of FCM is identical to the value for the NL 4 (3.35 MJ of NE_L/kg of FCM) presented in this study (Table 7).

The NL-dependent and differentiated NE_L requirement per kilogram of FCM deduced in our investigations allows a better adjustment to the respective level of feeding or performance. Relating the remaining energetic impact for production of 40 kg of FCM (resulting from the decline of digestibility) to the DMI results in needing an additional DMI of 0.4 kg between the NL.

Nevertheless, henceforth it has to be considered that a substantial variation in NE_L input per kilogram of FCM above the maintenance requirement exists within the dairy cattle population (with a trend of decreasing NE_L input per kilogram of FCM at increasing performances). Hence, it is debatable whether the relation between the decrease of energy digestibility and the according partial compensation of the energy loss by concomitant reduction of the loss of methane energy and urine energy with rising NL, as used in Table 6, are still valid if the NL is higher than 3.5.

CONCLUSIONS

These studies confirm the decrease in digestibility of energy when NL increases to more than 3.5 in dairy cows. The rate of depression in digestibility of energy amounted to 4.1% for each increase in NL. Based on earlier investigations, the urinary energy and methane energy losses decrease with increasing NL. Taking into account the equations for calculating of urine and methane energy in relation to NL, the NE_L content declines only by 1.6% as the NL increased by one unit. The relationships between urinary and methane energy and the NL have not been investigated yet for NL higher than 3.5. For future investigations, analogous experiments with other ration ingredients, as well as higher or lower energy concentrations of the ration, in combination with whole metabolism measurements are also necessary for a more reliable and generally valid quantification of the problems related to the effect of the decline of digestibility on the adequate energy supply of high-yielding dairy cows.

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