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Effect of different degraded protein balances (OEB) on the performance of beef bulls and on digestibility and rumen fermentation in sheep[1]

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Abstract

One-hundred and twenty-five non-double-muscled Belgian Blue finishing bulls (live weight range 375–620 kg) were used to investigate the effect of different levels of degraded protein balance in the rumen (OEB; –2, –7, –16 and –22 g kg^{-1} dry matter; DM) on animal performance, with the dietary content of true protein digested in the small intestine (DVE) fixed at 80 g kg^{-1}. Lower OEB levels significantly reduced daily liveweight gain from 1.57 to 1.39 kg during the first 84 days of the experiment, but not during the subsequent part. For the whole experiment, daily liveweight gain decreased from 1.40 to 1.32 kg but the difference was not significant. Intake of DM, DVE and net energy for fattening was not modified by OEB level, while crude protein intake was reduced and OEB lack was increased. An OEB level of –22 g kg^{-1} DM resulted in a significantly unfavourable conversion of DM and net energy during the initial months (11.3 and 11.5% compared to OEB = –2 g kg^{-1} DM, respectively). For the total period the conversion of DM and net energy was still less favourable, but the differences were not significant. There was a nominal decrease in cold carcass weight and dressing proportion when OEB level decreased, but the effect was not significant.
The effect of different OEB levels on digestibility and rumen fermentation was investigated in a separate experiment with wethers. Apparent protein digestibility was reduced from 74.2 to 68.9% when OEB level decreased. Rumen pH and concentrations and molar percentages of volatile fatty acids were not altered by OEB level. Ammonia concentration was only reduced by a lower OEB level at 7 hr after feeding.
Because of a nominal reduction in daily liveweight gain, feed efficiency, carcass weight, dressing percentage and carcass conformation with decreasing OEB level, it is advisable not to feed less than –16 g OEB kg^{-1} DM in diets with 80 g DVE kg^{-1} DM to Belgian Blue non-double-muscled finishing bulls from 375 kg onwards. This tolerable OEB lack is larger than proposed in case of protein overfeeding.

Keywords: degraded protein balance, beef bulls, performance, carcass quality, digestibility, rumen fermentation

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Introduction

The protein content of each feed is characterised by two values in most of the new protein evaluation systems (Anonymous, 1988; Madsen, 1985; Tamminga *et al*., 1994). Although differences exist in the mode of expression between the protein systems, the values are composed of the digestible true protein contributed by the rumen bypass feed protein and the microbial protein synthesised in the rumen. A certain equilibrium in the diet is desirable, meaning that the rumen protein balance (PDIN – PDIE, Anonymous, 1988; PBV, Madsen, 1985; OEB, Tamminga *et al*., 1994) should be close to zero in their respective systems. However, small negative values in growing cattle can be tolerated, because of the nitrogen recycling. The Dutch protein system only allows a lack of OEB (degraded protein balance in the rumen) in animals weighing more than 250 kg, when the DVE (true protein digested in the small intestine) intake exceeds the DVE requirement. In the French protein system the lack of nitrogen available for rumen microbes is expressed per unit of energy. Based on these two protein systems, differences in minimal rumen available nitrogen may occur. According to the Dutch system the OEB lack in a 450 kg bull may account to 50 g OEB daily. If we assume a DM intake of 8.1 kg for 450-kg weighing bulls (Fiems *et al*., 1999) with 7.62 MJ net energy value for fattening (NEF) per kg DM, then the tolerable OEB lack can rise to more than 100 g, based on the French protein system. This is considerably higher than in the Dutch system. When the DVE/OEB system was introduced, Tamminga et al. (1994) stated that the influence of a negative OEB level was yet to be demonstrated. This paper deals with the effect of different OEB-values with a similar DVE content in diets for finishing beef bulls.

Materials and methods

Beef production experiment

One hundred and twenty-five non-double-muscled Belgian Blue bulls, purchased in the market, were used in three series (41, 48 and 36 bulls, respectively) over three consecutive years. After an adaptation period of approximately 2 months and at a live weight (LW) of 376 kg, the bulls were divided into four comparable groups based on LW, age, conformation score, and LW gain during the adaptation period. Seventy-two animals, equally divided over the 4 groups, were confined in loose houses with slatted floors (6 bulls per pen). The other bulls were housed in straw-bedded tie stalls. Animals were weighed on three subsequent days at the start, and on two subsequent days after 84 days and at the end of the trial after 138 to 222 days.

The diet consisted of maize silage and concentrates (65/35 on a DM-basis). They were distributed once daily, adjusting the amount offered to minimize refusals, but always with respect to the concentrate/roughage ratio. Both feeds were fed separately at the same time. The concentrates were formulated to give a similar DVE content of 80 g per kg dietary DM. The pre-arranged OEB levels, based on tabular values for concentrate ingredients (Anonymous, 1994) and tabular coefficients (Anonymous,

1991) and actual analysis for maize silage, were +2, –6, –14 and –22 g per kg dietary DM for the respective groups. These OEB levels were maintained throughout the entire experiment. The ingredients of the concentrates are listed in Table 1. Drinking water was always available.

A jugular blood sample was taken after 61 and 145 days, only during the first series (11, 10, 10 and 10 animals, respectively), to determine blood urea nitrogen (BUN).

The animals were weighed after a feed withdrawal of 20 hr and then slaughtered. Water was withdrawn for 16 hr prior to slaughter. Dressing percentage was calculated and carcasses were classified according to the SEUROP-scheme (Anonymous, 1981). The 8th-rib-cut from the right carcass half was removed to estimate the carcass composition as described by Verbeke & Van de Voorde (1978).

Digestibility and rumen fermentation experiment

The digestibility of the diets was estimated with five rumen-fistulated wethers per series, fed at maintenance level for energy, using a latin square design. The collection period lasted 10 days and was preceeded by a 14-day adaptation period. After the digestibility trial, the feeding level was increased up to ad libitum. Rumen fluid samples were taken during three consecutive days, immediately before feeding and at 3.5 and 7 hrs postprandial, starting at the 5th day after the end of the digestibility trial. Volatile fatty acids (VFA) were determined by gas chromatography on the sample taken at 3.5 hrs postprandial. Ammonia and pH were determined on the three samples.

Chemical analyses

Weende components of the feeds were analysed according to the EU methods. DVE and OEB-values of the feeds were estimated as described by De Boever *et al*. (1995). The NEF (Van Es, 1977) was calculated based on in vitro techniques (De Boever *et*

Table 1. Ingredients in the experimental concentrates (kg ton^{-1}).

	Pre-arranged dietary OEB level (g kg^{-1} DM)			
	+2	–6	–14	–22
Soyabean meal	300	261.5	257.3	64.7
Treated soyabean meal*	–	–	–	84
Maizeglutenfeed	250	211	64	250
Coconut cake	–	46.3	77	72.3
Rapeseed meal	66	66	40	–
Malt sprouts	56	–	–	–
Barley	134.7	92.5	73	42
Beet pulp	16	147	312.7	311.3
Beet molasses	60	60	60	60
Tallow	20	20	20	20
Mineral, trace element and vitamin premix	77.3	75.7	76	75.7
Binder (Pelletin-Mg, Zell-Lignin, Germany)	20	20	20	20

* Treated with formaldehyde (trade name: Rumi-S, Schouten Industries, Giessen, The Netherlands).

Table 2. Chemical analysis and nutritive value of the feeds.

	Concentrates				Maize silage
Dietary OEB level (g kg^{-1} DM)	–2	–7	–16	–22	
Chemical analysis (g/kg)					
Dry matter (DM)	885	887	889	892	350
Composition of DM					
Crude protein	258	240	219	192	71
Ether extract	46	48	44	48	29
Crude fibre	73	88	107	108	194
Ash	105	106	108	106	47
Nutritive value of DM					
NEF (MJ)	7.99	8.16	8.23	8.16	6.84
DVE (g)	130	128	131	125	56
OEB (g)	75	59	36	16	–43

al., 1998). The chemical composition and the nutritive value of the feeds are shown in Table 2.

The BUN was determined according to the Berthelot method (Anonymous, 1992). The method of Voigt and Steger (1967) was used for the analysis of ammonia, while the analysis of the VFA in the rumen fluid was carried out according to Supelco (Anonymous, 1997).

Statistical analyses

No significant interactions were found between OEB level, series, and housing with regard to animal performance and carcass data. However, a series effect was observed for intake and feed conversion during the second part of the experiment and the whole experiment, but this was not considered as being of main importance within the context of this experiment. Therefore, the results are presented based on a one-way analysis of variance, whereas treatment means are ranked for significance using the Newman-Keuls test. Analysis of intake and feed conversion (intake per kg liveweight gain) was based on means of tied animals and pen means of loose-housed bulls per series and per treatment. Also treatment effects on digestibility and rumen fermentation were estimated using a multiple analysis of variance with series and treatment as the main factors for digestibility and series, treatment and sampling day as the main factors for the fermentation characteristics. Treatment means were again ranked for significance by the Newman-Keuls test.

Results

Beef production experiment

Protein concentrations per kg DM of the diets averaged –2, –7, –16 and –22 g OEB, and 135, 129, 121 and 112 g crude protein, respectively, whereas DVE-content only

Table 3. Effect of dietary OEB level on liveweight gain.

	Dietary OEB level (g kg^{-1} DM)				Pooled s.e.
	–2	–7	–16	–22	
Number of bulls	32	31	31	31	
Initial weight (kg)	376.2	376.4	376.2	375.8	28.8
Weight after 84 days (kg)	507.8	500.3	501.5	492.5	42.2
Final weight (kg)	622.7	613.7	620.5	607.9	41.7
Experimental days	176.3	174.8	174.8	176.0	23.0
Daily gain (kg)					
1–84 days	1.57[a]	1.48[ab]	1.49[ab]	1.39[b]	0.26
85th day – end	1.24	1.29	1.30	1.25	0.29
total period	1.40	1.40	1.39	1.32	0.21

[ab] Values without or with the same superscripts are not significantly different (P>0.05).

ranged between 80 and 82 g. During the first 84 experimental days, daily LW gain was decreased with decreasing OEB level (Table 3). However, from 85 days onward, the animals with an OEB level of –7 and –22 realized a small but nonsignificant compensatory gain, so that the overall daily LW gain was not different among groups.

There was no clear effect of the OEB level on the daily intake of DM, energy and DVE, while both crude protein and OEB intake were different among treatments (see Table 4). OEB intake per kg metabolic weight averaged –0.1, –0.6, –1.3 and –2.0 g during the first sub-period, –0.2, –0.6, –1.3 and –2.4 g during the second sub-period, and –0.1, –0.6, –1.3 and –1.9 g during the total period, respectively. The significant effect of OEB level on liveweight gain, without an effect on feed intake resulted in a different conversion of DM and NEF during the initial sub-period. Only crude protein conversion was altered during the second sub-period, whereas the differences were not significant during the total period (Table 5). Intake per kg carcass gain, assuming an initial dressing percentage of 59, resulted in a worse conversion of DM, DVE and NEF when the OEB level decreased from –2 to –22 g kg^{-1} DM, raising up to 10, 8 and 10%, respectively, while crude protein conversion was improved by 9% in comparison with OEB = –2 g kg^{-1} DM.

BUN was significantly decreased when the OEB level decreased. It amounted to 93.3, 90.5, 76.5 and 60.5 (±18.8) mg per l., respectively, after 61 days, with 93.3 and 90.5 being different from 60.5(P<0.05). Values after 145 days were higher than after 61 days, and averaged 102.5, 101.7, 72.3 and 62.0 (±18.4) mg per l., respectively, with 102.5 and 101.7 being higher than 72.3 and 62.0(P<0.05).

A lower OEB level resulted in a non-significant reduction of the cold carcass weight (P>0.05). There was also a non-significant reduction of the dressing percentage, whereas the SEUROP conformation score was different between –2 and –22 g OEB kg^{-1} DM (Table 6). Carcass composition was not modified by OEB level, except for the percentage of bone.

Table 4. Effect of dietary OEB level on feed intake.

	Dietary OEB level (g kg^{-1} DM)				Pooled s.e.
	–2	–7	–16	–22	
1-84 days					
Concentrate (kg)	3.43	3.34	3.31	3.41	0.33
Maize silage (kg)	16.31	15.87	15.82	16.00	2.17
Dry matter (kg)	8.59	8.35	8.32	8.47	0.83
NEF (MJ)	51.37	50.04	50.09	50.78	10.02
Crude protein (kg)	1.17^{a}	1.08^{ab}	1.02^{b}	0.96^{b}	0.10
DVE (kg)	0.70	0.68	0.69	0.68	0.07
OEB (kg)	–0.01^{a}	–0.06^{b}	–0.13^{c}	–0.19^{d}	0.06
85th day – end					
Concentrate (kg)	3.64	3.50	3.63	3.58	0.23
Maize silage (kg)	17.21	16.62	17.16	17.02	2.48
Dry matter (kg)	9.19	8.86	9.18	9.08	0.59
NEF (MJ)	55.85	54.10	56.09	55.46	11.11
Crude protein (kg)	1.23^{a}	1.14^{ab}	1.11^{bc}	1.01^{c}	0.09
DVE (kg)	0.74	0.72	0.75	0.72	0.06
OEB (kg)	–0.02^{a}	–0.07^{b}	–0.15^{c}	–0.21^{d}	0.02
Total period					
Concentrate (kg)	3.54	3.42	3.48	3.50	0.23
Maize silage (kg)	16.78	16.26	16.52	16.53	2.19
Dry matter (kg)	8.90	8.62	8.77	8.79	0.60
NEF (MJ)	53.72	52.15	53.21	53.23	10.32
Crude protein (kg)	1.20^{a}	1.11^{ab}	1.06^{bc}	0.99^{c}	0.08
DVE (kg)	0.72	0.70	0.72	0.70	0.06
OEB (kg)	–0.02^{a}	–0.06^{b}	–0.14^{c}	–0.20^{d}	0.02

^{abcd} Values without or with the same superscripts are not significantly different (P>0.05).

Digestibility and rumen fermentation experiment

The digestibility coefficients of the 4 diets are given in Table 7. OEB level did not affect the digestibility of most diet components. Only the apparent protein digestibility was decreased when the OEB level was reduced, probably as a result of the relative increase of endogenous protein.

The OEB level did neither affect pH nor the total amount and the individual concentration of VFA in the rumen fluid (Table 8). Ammonia level was reduced when the OEB level decreased, but only 7 hr postprandial.

Discussion

It is well known that the protein content of the diet can exert an influence on the animal performance (De Boer & Hamm, 1977; Boucqué *et al*., 1984; Fiems *et al*., 1995). However, the dietary protein content, expressed as DVE, was similar for the

Table 5. Effect of dietary OEB level on feed conversion.

	Dietary OEB level (g kg^{-1} DM)				Pooled s.e.
	–2	–7	–16	–22	
1-84 days					
Dry matter (kg)	5.48^{a}	5.66^{ab}	5.58^{ab}	6.10^{b}	0.40
NEF (MJ)	32.79^{a}	33.93^{ab}	33.58^{ab}	36.55^{b}	5.02
Crude protein (kg)	0.75	0.74	0.68	0.69	0.06
DVE (kg)	0.45	0.46	0.46	0.49	0.03
85th day – end					
Dry matter (kg)	7.38	7.09	7.04	7.24	1.45
NEF (MJ)	44.87	43.31	43.02	44.21	10.52
Crude protein (kg)	0.98^{a}	0.91^{ab}	0.85^{b}	0.81^{b}	0.15
DVE (kg)	0.60	0.57	0.57	0.58	0.10
Total period					
Dry matter (kg)	6.37	6.35	6.29	6.67	0.65
NEF (MJ)	38.42	38.41	38.16	40.35	6.62
Crude protein (kg)	0.86	0.82	0.76	0.75	0.07
DVE (kg)	0.52	0.52	0.52	0.53	0.04

^{abcd} Values without or with the same superscripts are not significantly different (P>0.05).

different treatments, but the protein quality was different. There was a gradual reduction of the protein degradability beside a reduced crude protein content, which was reflected in a decreased OEB level. A decreased OEB level reduced the daily LW gain during the initial months of the finishing period (LW interval 375–500 kg). Afterwards, no effect from the OEB level was observed for –22 g OEB, or even a slight compensatory gain was realised for –7 and –16 g OEB. This may be provoked by more nitrogen available for recycling (higher BUN) and more energy available for

Table 6. Effect of dietary OEB level on carcass characteristics.

	Dietary OEB level (g kg^{-1} DM)				Pooled s.e.
	–2	–7	–16	–22	
Slaughter weight (kg)	620.3	600.7	607.3	593.9	41.9
Cold carcass weight (kg)	386.9	374.3	380.5	369.6	31.3
Dressing (%)	63.4	62.3	62.7	62.2	1.9
SEUROP-classification					
Conformation	11.5^{a}	11.1^{ab}	10.9^{ab}	10.5^{b}	1.5
Fat covering	7.2	7.6	7.4	7.0	1.3
Carcass composition (%)					
Meat	67.0	66.3	66.4	66.2	2.6
Fat	19.3	20.6	20.4	20.1	3.1
Bone	13.7^{a}	13.1^{b}	13.2^{ab}	13.7^{a}	1.2

^{ab} Values without or with the same superscripts are not significantly different (P>0.05).

Table 7. Effect of dietary OEB level on digestibility in sheep.

	Dietary OEB level (g kg^{-1} DM)				Pooled s.e.
	–2	–7	–16	–22	
Dry matter	77.0	77.7	77.3	77.2	1.9
Organic matter	80.1	80.6	80.4	80.3	1.9
Crude protein	74.2[a]	73.2[a]	71.6[a]	68.9[b]	3.8
Ether extract	86.7	86.9	86.6	86.5	2.5
Crude fibre	67.3	69.5	69.0	70.2	4.4
N-free extract	84.2	84.8	84.9	84.7	1.2
Gross energy	77.9	78.4	78.0	77.9	2.1

[ab] Values without or with the same superscripts are not significantly different (P>0.05).

microbial protein synthesis and a lower DVE requirement in heavier animals, which is in agreement with a larger tolerable OEB-lack in heavier animals, as proposed by Van Vliet *et al*. (1994). It is possible that the slight compensatory gain during the second sub-period was due to the fact that the OEB and DVE levels were maintained during the total period. In an experiment of Heeres-van der Tol & Plomp (1996) there was a simultanous decrease in OEB (from 0 to –22 g kg^{-1} DM) and DVE (from 83 to 62 g kg^{-1} DM), and no compensatory effect was observed. It is not clear why there was no compensatory gain for the –22 g OEB kg^{-1} DM in comparison with –16 g

Table 8. Effect of dietary OEB level on rumen fermentation characteristics of sheep.

	Dietary OEB level (g kg^{-1} DM)				Pooled s.e.
	–2	–7	–16	–22	
Volatile fatty acids (VFA, mmol/L)	96.6	95.8	98.7	95.7	1.7
Molar % of VFA					
Acetic acid	63.6	64.8	62.8	63.0	3.6
Propionic acid	18.9	18.6	20.6	21.4	4.5
Butyric acid	14.3	14.0	14.2	13.1	2.7
Isobutyric Acid	0.7	0.7	0.6	0.5	0.2
2-Methylbutyric acid	0.5	0.4	0.4	0.4	0.4
Valeric acid	1.3	1.2	1.1	1.2	1.2
Isovaleric acid	0.6	0.5	0.4	0.4	0.2
Ammonia (mg/L)					
before feeding	32.8	31.1	29.5	27.3	6.5
3.5 hr postprandial	36.3	34.1	32.7	31.1	7.6
7 hr postprandial	27.3[a]	26.9[a]	24.5[ab]	18.5[b]	6.6
pH					
before feeding	6.96	6.91	6.99	7.06	0.20
3.5 hr postprandial	6.12	6.19	6.18	6.10	0.20
7 hr postprandial	6.61	6.64	6.61	6.61	0.20

[ab] Values without or with the same superscripts are not significantly different (P>0.05).

Table 9. Verification of tolerable OEB level.

	Dietary OEB level (g kg^{-1} DM)			
	–2	–7	–16	–22
1-84 days				
Daily DVE intake (g)	703	681	688	682
Daily OEB lack (g)	8	57	128	186
DVE requirement[a] (g)	569	545	549	522
Tolerable OEB-lack (g)				
Equation 1[b]	48	47	47	46
Equation 2[c]	206	209	214	246
84th day-end				
Daily DVE intake (g)	741	716	749	723
Daily OEB lack (g)	21	65	145	205
DVE requirement[a] (g)	555	563	565	549
Tolerable OEB-lack (g)				
Equation 1[b]	79	77	78	75
Equation 2[c]	286	235	283	268

[a] Based on LW and LW gain as mentioned in Table 3
[b] (LW-250)*0.25
[c] DVE-intake – DVE requirement)/0.65.

OEB kg^{-1} DM. For both treatments BUN was hardly different between the second part of the experiment (72.3 and 62.0 mg l^{-1}) compared to the first part (76.5 and 60.5 mg l^{-1}). Higher BUN-values were obtained with diets containing a higher OEB level. They are generally reflective of an increased protein intake (Preston *et al*., 1965; Leibholz, 1970). Higher BUN-values were also obtained in heavier animals, suggesting that additional protein was utilised less efficiently in older animals (Fiems *et al*., 1997). The non-detrimental effect of OEB levels of –7 and –16 corresponded with a dietary crude protein level of 12.9 and 12.1%. This is in agreement with a crude protein level of 12%, previously recommended by Boucqué *et al*. (1980).

Feed intake may be affected by protein levels. Ketelaars & Tolkamp (1992) showed that the range of dietary protein content over which a positive effect is seen, far exceeds values that may limit ruminal microbial fermentation. The crude protein levels in this experiment ranged between 112 and 135 g per kg DM, but did not affect DM and NEF intake.

The worse feed conversions, obtained with –22 g OEB kg^{-1} DM, may be due to a lower LW gain, resulting in a relatively higher maintenance requirement. We assume a negligible effect of OEB level on the energy value of the diets, as the organic matter digestibility and the concentration of VFA in the rumen of sheep were not different.

Lower OEB levels and ditto crude protein levels did not result in a reduced dressing proportion. However, the differences were significant when dressing was adjusted for the lower carcass weight. It is well known that dressing is positively related

with carcass weight (Van De Voorde & Verbeke, 1979). Lower dietary protein concentrations also decreased the dressing proportion in experiments of Boucqué *et al*. (1980 and 1984). On the other hand, meat content in the carcass was not modified. Nevertheless, results of Berge *et al*. (1993) have shown that muscle content in the carcass can be altered by different dietary protein levels.

An OEB lack can be tolerated, assuming that the daily OEB lack is smaller than the smallest value from two equations: '(LW-250)*0.25' on the one hand, and '(DVE-intake – DVE-requirement)/0.65', on the other hand (Van Vliet *et al*., 1994). Using these equations and the mean LW and feed intake during the two sub-periods, we can calculate the maximum tolerable OEB lack (see Table 9). Based on a similar LW gain and feed conversion in the third treatment group as in the first and the second treatment group during the first part of the experiment (see Tables 3 and 5, respectively), we conclude that the tolerable OEB lack contains a safety margin, mainly because the first criterion is too restrictive. Obviously, an OEB value of –16 g kg^{-1} DM is still acceptable with regard to animal performance and carcass quality.

At a similar DVE-content, the reductions in OEB level only decreased apparent protein digestibility. Tritschler *et al*. (1984) also found that crude protein only affected protein digestibility. However, in a previous study we found that a lower protein level decreased digestibility of all feed components, except crude fibre and fat (Fiems *et al*., 1997). Similar to DM and organic matter digestibility in the present experiment, ruminal VFA-concentration and molar percentages were neither changed by OEB level, suggesting a comparable content of fermentable organic matter in the diets. Jones *et al*. (1973) reported a different VFA-concentration and a different molar percent of acetate for different dietary protein levels. According to Mehrez *et al*. (1977) a maximum rate of fermentation occurs at a minimal ammonia concentration of 235 mg/l. rumen fluid. Only the rumen fluid from the lowest OEB level, sampled 7 hr after feeding, was below this threshold and was lower than in the two diets with the highest OEB levels. The fact that we did not find an influence of OEB level on rumen pH was in accordance with the results of Jones *et al*. (1973). Regarding nitrogen recycling, the transposition of results obtained in adult sheep to growing-finishing bulls must be interpreted with care, as the protein requirements in both types of animals are different.

It can be concluded from this experiment that a negative OEB-value between –7 and –16 g kg^{-1} dietary DM, beside an overfeeding of DVE (80 g per kg dietary DM), is still acceptable during a LW-range from 375 to 620 kg. This also means that the amount of nitrogen available in the rumen is more restrictive in the Dutch than in the French protein system.

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