Effects of rare earth elements (REE) supplementation to diets on the health and performance of male and female pre-ruminant calves and growing female calves

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Abstract

Two feeding trials with pre-ruminant and growing Holstein calves were carried out in order to investigate the effect of rare earth elements (REE) on feed intake and performance parameter. In the first experiment, applying a complete two by two factorial design, 87 calves (45 female and 42 male) with a mean age of 9.6 ± 1.8 days were randomly assigned to one of two treatments (Con or REE). The animals received milk replacer either with or without 200 mg/kg REE-citrate containing mainly cerium (57.9 %), lanthanum (34.0 %) and praseodymium (6.5 %) as well as concentrate and grass hay over a period of 44 days. The feed intake and performance parameter were not significantly and interactively affected by sex and REE supplementation. However, the supplemented animals consumed numerically less concentrate (13.5 %) and grass hay (26.3 %) compared to control animals which led to a slightly reduced live weight gain (496 g/day in REE group vs 525 g/day in control group). In the second experiment, a total of 47 growing female calves (average initial live weight of 108 ± 9 kg) were divided into four treatment groups (n = 11 or 12 per group): one control group and three REE-treated groups fed a supplement of 100, 200 and 300 mg REE-citrate per kg dry matter (DM). The calves were offered grass silage, grass hay and concentrate. The experiment was terminated when the calves reached a live weight of approximately 182 kg. The feed intake, live weight gain, feed-to-gain ratio and ME-to-gain ratio were not significantly influenced by increasing REE-citrate supplementation. Also, a numerically tendency towards reduced feed intake and live weight gain could be observed for the group fed with the highest amounts of REE. Thus, it can be concluded that REE-citrate are not suited to improve the performance of calves.

Keywords: pre-ruminant, female calves, rare earth elements; growth performance

Zusammenfassung

Einfluss des Einsatzes von seltenen Erden in der Fütterung von männlichen und weiblichen Kälbern und Jungrindern auf Gesundheits- und Leistungsparameter

Zur Bestimmung des Einflusses Seltener Erden (REE) in der Ernährung von Kälbern und Jungrindern auf deren Futteraufnahme und verschiedene Gesundheits- und Leistungsparameter wurden zwei Versuche durchgeführt. Im ersten Experiment erhielten 87 Kälber (45 weiblich und 42 männlich) über einen Zeitraum von 42 Tagen beginnend mit einem mittleren Alter von 9.6 ± 1.8 Tagen Milchaustauscher mit oder ohne Zulage von 200 mg/kg REE-Zitrat, Kraftfutter und Heu. Das REE-Zitrat enthielt hauptsächlich Cer (57.9 %), Lanthan (34.0 %) und Praseodym (6.5 %). Die REE-Supplementierung führte zu keiner signifikanten Beeinflussung der Futteraufnahme und der Leistungsparameter. Dennoch nahmen die mit REE supplementierten Tiere 13.5 % weniger Kraftfutter und 26.3 % weniger Heu auf, was zu einer geringfügig reduzierten Lebendmassezunahme von 496 g/Tag in der REE-Gruppe gegenüber 525 g/Tag in Kontrollgruppe führte. Im zweiten Experiment wurden 47 Jungrinder mit einer mittleren Lebendmasse von 108 ± 9 kg in vier Gruppen mit 11 oder 12 Tieren aufgeteilt. Neben einer nicht supplementierten Kontrollgruppe wurden drei Versuchsgruppen mit 100, 200 und 300 mg REE-Zitrat je kg Trockenmasse supplementiert. Die Tiere erhielten bis zum Versuchsende mit einer Lebendmasse etwa 182 kg Grassilage, Heu und Kraftfutter. Die Futteraufnahme, die Lebendmassezunahme und die Futterverwertung wurden nicht durch die REE-Supplementation beeinflusst, wobei ein Trend zu einer geringeren Futteraufnahme und einer verminderten Lebendmassezunahme in der am höchsten supplementierten Gruppe beobachtet wurde. Unter den in den Versuchen vorliegenden Bedingungen führte die Zulage von Seltenen Erden nicht zu einer verbesserten Leistung der Tiere.

Schlüsselwörter: nicht ruminierend, weibliche Kälber, Seltene Erden, Wachstumsleistung

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1 Introduction

In China, it was discovered that rare earth elements (REE) could stimulate the growth of agricultural products and food producing animals, hence they have been used successfully for decades in farms as fertilizer and as feed additive, mainly containing lanthanum, cerium, praseodymium and neodymium (Redling, 2006). Based upon this information, trials were performed under European production conditions with the aim to find new substances in order to replace antibiotics as growth promoters. Also, in several Western feeding studies it could be shown that dietary supplementation of REE had positive effect on both weight gain and feed conversion rate of pigs and poultry (He and Rambeck, 2000; He et al., 2001; He et al., 2010). In a Swiss study, Kessler (2004) showed, that supplementation of 200 mg REE-citrate in diet of pigs significantly improved daily live weight gain by 8.8 % and significantly decreased feed-to-gain ratio by 3.6 %. In this study, it was particularly interesting and has not been described before that the effect in female pigs was roughly twice as high as in castrated pigs. Up to now, only a limited number of investigations on ruminants at different genders and periods of growth, including rearing, growing and fattening are available in the literature and the obtained results of REE are controversial. Schwabe et al. (2009) observed after a supplementation of REE to diet for 32 weeks adverse effects on live weight gain, feed-to-gain ratio and metabolizable energy-to-gain ratio of fattening bulls (initial live weight 245 kg), while Miller (2006) found no effect on live weight gain after an application of REE on growing male calves (initial live weight 83 kg, average age 44 days) for 10 weeks. In contrast to that, positive effects on performance due to REE supplementation were observed by Meyer et al. (2006) on pre-ruminant female Holstein calves. Based upon these findings, it might be possible that age and gender play a role regarding efficiency of REE. Therefore, the objective of these two feeding studies was to investigate the effect of REE on feed intake and growth performance focused on pre-ruminant female and male calves as well as on growing female Holstein calves.

2 Material and methods

2.1 Treatments, experimental design and animals

Two feeding experiments were conducted at the Experimental Station of the Institute of Animal Nutrition, Friedrich-Loeffler-Institute (FLI) in Braunschweig, Germany.

In feeding experiment 1, a total of 87 calves (42 male and 45 female) of the "German Holstein breed" from the milk cattle herd FLI-Braunschweig were used. They were born between October 2006 and March 2007 and separated from their dams one day after birth, and moved into individual straw-bedded calf hutches (87 x 175 cm) in an adjacent thermally non-regulated stable. In the first seven days of life, each calf received six litres of colostrum per day and then milk replacer (manufacturer, Norlac GmbH, Zeven), divided into two equally-sized portions, in the morning and afternoon from teat buckets. After 9.6 ± 1.8 days, the calves were randomly assigned to one of two treatments (Con or REE) for 44 days and kept separately in two identical pens with straw bedding in the same building. Each calf started individually with the trial depending on its day of birth. After transfer to the group pens, the calves were fed 600 g milk replacer at a concentration of 100 g/L water per animal and day up to day 43 and 200 g per calf on day 44 supplemented either with or without 200 mg REE-citrate/kg milk replacer via a computer-controlled milk feeder. The supplement (Lancer® 500, Zehentmayer AG Berg, Switzerland) consists of 50 % wheat starch and 50 % lanthanoide, whereby the lanthanoide (REE-citrate) itself consisted of 25.3 % rare earth elements and 74.7 % citrate, respectively. The REE-citrate was a mixture containing organic citrate compounds of 57.9 % cerium, 34.0 % lanthanum, 6.5 % praseodymium and 1.6 % of other rare earth elements. In addition to milk replacer, the calves had free access to grass hay and concentrate up to 1 kg per calf and day by using concentrate feeder from the beginning of the trial. Water was continuously provided by bowl drinkers. The composition of the milk replacer and the concentrate is presented in Table 1 and 2. Each calf was equipped with an ear transponder recording continuously the daily individual feed intake of milk replacer and concentrate, however, the hay intake was measured daily per group. The live weight [LW] of calves was measured at the start and end of the study with cattle scales.

Table 1:

Composition of the milk replacer [g/kg] used in the milk feeding period

Group	Control	REE 200
Components		
Skim milk powder	505	505
Whey powder	289	289
Palm-coconut-soya oil	173	173
Wheat starch	30	29.6
Mineral and vitamin premix*	3	3
Lancer®500†	-	0.4

Notes: *per kg mineral and vitamin premix: 8 g Ca; 7.5 g P; 100 mg Fe; 8 mg Cu; 100 mg Zn; 50 000 IU vitamin A; 3.300 IU vitamin D_3; 80 mg vitamin E; 150 mg vitamin C; 8 mg vitamin B_1; 7 mg vitamin B_2; 4 mg vitamin B_6; 50 mcg vitamin B_{12}; 8 mg vitamin K_3; 150 mcg Biotin; †Lancer®500 consists of 50 % wheat starch and 50 % lanthanoide

Table 2:

Composition of the concentrates [g/kg] used in the milk feeding period (MFP) and growing period (GP)

Group		A	B	C	D
	Con/REE	Control	REE 100	REE 200	REE 300
Period	MFP	GP	GP	GP	GP
Components					
Soy bean meal	300	300	300	300	300
Oats	305	305	305	305	305
Barley	180	180	180	180	180
Wheat	170	170	169.7	169.4	169.1
Soybean oil	15	15	15	15	15
Calcium carbonate	10	10	10	10	10
Mineral and vitamin premix*	20	20	20	20	20
Lancer®500†	0	0	0.3	0.6	0.9

Notes: *per kg mineral and vitamin premix: 160 g Ca; 100 g Na; 80 g P; 30 g Mg; 1000 mg Fe; 800 mg Cu; 4000 mg Mn; 6000 mg Zn; 50 mg I; 50 mg Se; 30 mg Co; 800 000 IU vitamin A; 80 000 IU vitamin D_3; 100 mg vitamin E; †Lancer®500 consists of 50 % wheat starch and 50 % lanthanoide

The feeding experiment 2 was carried out with 47 female German Holstein calves and started with a stepwise inclusion of animals according to the calving of the FLI-milk cattle herd. At the beginning of the trial the calves had an average initial LW of 108 ± 9 kg and an average age of 14 ± 0.4 weeks. They were randomly assigned to one of four treatment groups with 11 or 12 animals each designated as groups A, B, C and D with an intended REE-citrate supplementation of 0, 100, 200 and 300 mg/kg dry matter in the diet, respectively, over the complete trial period. During this time, the calves were housed in an unheated and non-insulated stable and were kept in group boxes according to their feeding group. The group pens with the dimensions 5.20 x 7.40 m were equipped with a slatted floor and partly covered with straw bedding. Grass silage and grass hay were available for *ad libitum* intake via computer controlled troughs (Type RIC, manufacturer: Insentec B.V., Marknesse, The Netherlands) and water via bowl drinkers. Additionally, each calf had access to 2.0 kg of concentrate per day from the concentrate station (Type AWS HF, manufacturer: Insentec B.V., Marknesse, The Netherlands), which was supplemented with or without REE. The precise composition of the concentrates is summarised in Table 2. The ration was formulated to meet the nutritional requirements for growing calves as recommended by the German Society of Nutrition Physiology (GfE, 2001). The daily intake of concentrate and roughage was recorded continuously by using an automated feeding system (Insentec B.V., Marknesse, The Netherlands) and ear transponder for each calf. The individual LW was measured automatically when calves entered the concentrate feeding station. The experiment was terminated when the individual calves reached a LW of approximately 182 kg.

2.2 Sample collection, preparation and analysis

Representative samples of the milk replacer, concentrate and grass hay were collected once, while grass silage samples were taken twice a week and pooled over approximately four weeks. During the collection period, the grass silage samples were stored at -19 °C and then dried at 60 °C for 72 h. For proximate analyses, all samples were ground to pass though a sieve with 1 mm pore size and homogenized. The composition of the feedstuffs (dry matter (DM), crude ash, crude protein, crude fat, crude fibre, acid detergent fibre and neutral detergent fibre) was determined according to the methods of the Association of German Agricultural Analysis and Research Centres (Seibold & Barth, 1976 to 1997) in the laboratory of the Institute of Animal Nutrition, Braunschweig. Additionally, the REE concentrations in feedstuffs and REE-citrate mixture (Lancer® 500) were determined by inductively coupled plasma-mass-spectrometry (Thermo ICP-MS X Series) according to the international standard DIN EN ISO 17294-2: 2005-02 in the laboratory of the Food GmbH Analytik–Consulting in Jena, Germany.

2.3 Calculations and Statistics

The metabolizable energy (ME) concentration of the diets was calculated by using the equation number 1.1.2 of the Society of Nutrition Physiology (GfE, 2001). The digestibilities of feedstuffs (milk replacer, concentrate and grass hay) were taken from the tabular values for each ingredient (DLG, 1997), whereas the ME concentration of grass silage was estimated by using the nutrient digestibilities from the standardised digestibility trial with four adult wethers according to the procedures as described by (GfE, 1991). The daily LW gain for both trials was calculated as the difference between the recorded live weight at the start and the end of the two experiments, divided by the number of days.

The performance parameters of experiment 1 were analyzed by a complete two by two factorial design of analysis of variance (ANOVA) according to the following model:

$$Y_{ijk} \quad \mu + a_i + b_j + axb(_{ij}) + e_{ijk} \qquad (1)$$

where

Y_{ijk} k^{th} observation related to the REE concentration i and sex j

μ overall mean

a_i	effect of dietary inclusion of REE (0; 200 mg REE-citrate/kg diet)
b_j	effect of the sex
$axb_{(ij)}$	interactions between REE concentration and sex
e_{ijk}	error term.

The performance parameters of experiment 2 were analyzed according to a one-way factorial design of analysis of variance (ANOVA) corrected for initial LW using the following model:

$$Y_{ij} = \mu + a_i + \beta_{y.x}(x_{ij} - \bar{x}\,..) + e_{ij} \qquad (2)$$

where

Y_{ij}	tested parameter of the calf"j" fed diet type "i"
μ	overall mean
a_i	effect of dietary inclusion of REE (0, 100, 200 and 300 mg REE-citrate/kg diet)
$\beta_{y.x}$	regression coefficient of y on x
x_{ij}	co-variable
$\bar{x}$	mean value for x
e_{ij}	error term

Results of AVONA are presented in the tables either as arithmetic means (Experiment 1) or as least square means (LSmeans; Experiment 2) and the pooled standard errors of means (PSEM). In case of significant treatment effects the Tukey-Test for multiple comparisons was used to identify significant mean value differences ($p < 0.05$).

The Statistica for Windows™ operating system (StatSoft Inc. 2007, Version 10.0) was used for all statistical evaluations.

3 Results

3.1 Composition and REE concentrations of feedstuffs used in experiment 1 and 2

The contents of crude nutrients and the REE (pure elements) concentrations of the analyzed feedstuffs milk replacer, concentrate and roughage as well as the Lancer 500® are summarised in Tables 3 and 4. The nutrient composition of the two milk replacers was almost equal and only very small differences in crude nutrients could be detected between control and supplemented concentrates (Tables 3 and 4). Negligible amounts of REE were detected in the unsupplemented milk replacer, whereas 9.5 and 17.0 mg total REE/kg DM were measured in the concentrate of experiment 1 and in the unsupplemented control concentrate of experiment 2. In the supplemented concentrates, total REE concentrations of 43, 90, 124 mg/kg DM were detected and were increased as intended by formulation. Also grass hay and grass silage, which were used as roughage contained low levels of REE (Tables 3 and 4).

Table 3:

Dry matter, nutrient composition and energy concentration of the milk replacer, concentrates and grass hay as well as the rare earth element (REE) contents in the milk feeding period

	Milk replacer				
REE-citrate supplementation [mg/kg DM]	0	200	Concentrate	Grass hay	REE-Citrate
Dry matter [g/kg]	961	961	883	863	
Crude nutrients [g/kg DM]					
Crude ash	78	77	64	62	
Crude protein	212	216	234	85	
Crude fat	141	142	42	15	
Crude fibre	-	-	67	303	
Acid detergent fibre	-	-	84	318	
Neutral detergent fibre	-	-	200	604	
Metabolizable energy [MJ/kg DM]	15.9	15.9	12.6	9.0	
Pure rare earth elements [mg/kg DM]					
Lanthanum	0.1	24	2	0.3	42 243
Cerium	0.1	41	4	0.6	73 395
Praseodymium	0.0	5	0.5	0.1	8 641
Neodymium	0.0	0.02	1.7	0.1	23
Remaining REE*	0.0	1	1.3	0.1	1 977
Total rare earth elements	0.2	71.02	9.5	1.2	126 279

Notes: *Without the element Scandium

Table 4:

Dry matter, nutrient composition and energy concentration of the concentrates, grass silage and grass hay as well as the rare earth element (REE) contents in the growing period

REE-citrate supplementation [mg/kg DM]	Concentrates				Grass silage	Grass hay	REE-citrate
	0	100	200	300			
Dry matter [g/kg]	889	894	890	889	342	870	
Crude Nutrients [g/kg DM]							
Crude ash	64	64	65	62	100	64	
Crude protein	223	216	210	213	150	95	
Crude fat	43	43	42	42	36	17	
Crude fibre	69	71	69	70	281	306	
Acid detergent fibre	88	89	87	89	308	323	
Neutral detergent fibre	207	216	213	212	520	609	
Metabolizable energy [MJ/kg DM]	12.6	12.6	12.6	12.6	9.5	9.0	
Pure rare earth elements [mg/kg DM]							
Lanthanum	5	13	29	41	0.5	0.2	42 243
Cerium	9	23	51	71	0.9	0.4	73 395
Praseodymium	1	3	6	9	0.1	0.1	8 641
Neodymium	1	2	2	1	0.2	0.1	23
Remaining REE*	1	2	2	2	0.2	0.1	1 977
Total rare earth elements	17	43	90	124	1.9	0.9	126 279

Notes: *Without the element Scandium

3.2 Performance parameters

3.2.1 Experiment 1

In the REE group, one male calf died on the 4th day of trial for unknown reasons and was not included in the statistical analysis. Furthermore, in both groups some calves were treated due to digestive and respiratory problems. The performance parameters of the pre-ruminant calves over the milk feeding period are shown in Table 5. The mean daily REE-citrate intake of the REE group was 111 mg/d or 123 mg/kg total DM. The initial and final weight was similar between the control and REE group and no interaction was observed between group and sex. However, a significant sex effect was observed at the start and the end of the experiment, as the female calves showed lower live weights than the male calves (Table 5). The mean intake of milk replacer and concentrate was not significantly affected by the REE supplementation, although numerically differences could be determined in the concentrate intake. The supplemented animals consumed 42 g/d (13.5 %) less concentrate than the control animals. With regard to the single group means it becomes obvious that this fact mainly result from the supplemented male calves (Table 5). Furthermore, the REE group showed a lower grass hay intake (26.3 %) compared to the control group, but no statistical analysis could be performed because the feed consumption was recorded daily per group. This depression in feed intake was reflected in the daily weight gain of the calves (496 g/day in REE group vs 525 g/day in control group). As a consequence of the lower feed intake the ME- and crude protein intake was influenced in a similar manner. The feed-to-gain ratio and ME-to-gain ratio was similar between the two groups (Table 5).

3.2.2 Experiment 2

The growth experiment 2 comprised the LW range between 108 ± 9 kg and 182 ± 14 kg and lasted approximately 11 weeks in total. During this time, no calf died and no health problems were observed. The average actual intake of REE-citrate/kg DM amounted to 0; 74 ± 7; 149 ± 13 and 225 ± 15 mg for the Group A, B, C, and D, respectively, and differed distinctly from the planned intake. The grass silage, grass hay and concentrate intake was not different among treatments. Although not statistically significant, the calves of Group D (300 mg REE-citrate/kg DM) consumed less grass silage (2.9 %) and grass hay (12.1 %) than the calves of the control group (Table 6). Hence, the total feed intake was the lowest for Group D with 4.02 kg DM/d followed by the Group C with 4.06 kg and Group B with 4.10 kg daily DM intake. The control

Table 5:

Effects of rare earth elements (REE) supplemented feed for calves on feed intake, live weight as well as live weight gain, feed-to-gain ratio and ME-to-gain ratio during the milk feeding period (Experiment 1)*

Group	Sex	Number of calves/ group	Feed intake [g DM/day] Milk replacer	Concen- trates	Grass hay	Total feed intake	Nutrient intake Crude protein [g/d]	Energy intake Metaboli- sable energy [MJ/d]	Pure REE [mg/kg DM]	Pure REE [mg/kg LW/d]	Initial weight [kg]	Final weight [kg]	Live weight gain [g/d]	Feed- to-gain ratio [kg/kg]	Metaboliza- ble energy – to gain ratio [MJ/kg]
Control	……	43	558	311	137	1006	204	14.0	3.1	0.05	43.4	66.5	525	2.00	27.9
REE	……	44	557	269	101	927	193	13.2	45.9	0.8	43.7	65.5	496	1.94	27.6
…..	female	45	558	295							41.1	63.3	504		
…..	male	42	556	283							46.1	68.9	518		
Control	female	22	560	300							40.8	62.9	502		
Control	male	21	555	321							46.2	70.4	549		
REE	female	23	557	291							41.4	63.7	506		
REE	male	21	557	245							46.1	67.5	486		
AVOVA (probability)															
Group			0.838	0.172	-‡	-	-	-	-		0.807	0.570	0.270	-	-
Sex			0.362	0.688	-	-	-	-	-		< 0.001	0.003	0.621	-	-
Group x Sex			0.383	0.291	-	-	-	-	-		0.756	0.380	0.212	-	-
PSEM			2	22	-	-	-	-	-		0.9	1.3	19	-	-

….. denotes that these effects were pooled
*Values are given as means and pooled standard errors of means (PSEM)
‡ No statistical analysis was carried out because the grass hay intake was measured daily per group and the probability of difference could not be calculated

Table 6:

Effects of rare earth elements (REE) supplemented feed for female calves on feed intake, crude protein intake, ME intake, live weight gain, feed-to-gain ratio and ME-to-gain ratio during the growing period from 108 kg to 182 kg body weight. (Experiment 2)*

Group	A	B	C	D		ANOVA (probabilities)		
REE-citrate [mg/kg DM]	0	100	200	300	PSEM	REE	Linear	Quadratic
Female calves/group	12	11	12	12				
Feed intake [kg DM/d]								
Grass silage	1.74	1.80	1.72	1.69	0.10	0.906	0.596	0.670
Grass hay	0.66	0.58	0.56	0.58	0.07	0.733	0.408	0.482
Concentrate	1.72	1.72	1.78	1.75	0.03	0.342	0.214	0.559
Total feed intake	4.12	4.10	4.06	4.02	0.10	0.857	0.387	0.938
Crude protein intake [g/d]	688	681	685	669	13	0.720	0.364	0.699
ME[#] intake [MJ/d]	44.2	44.0	43.7	43.3	0.9	0.901	0.458	0.883
Live weight gain [g/d]	994	997	991	972	17	0.739	0.352	0.525
Feed-to-gain ratio [kg/kg]	4.18	4.13	4.11	4.15	0.10	0.966	0.818	0.666
ME-to-gain ratio [MJ/kg]	44.8	44.3	44.3	44.7	1.0	0.981	0.970	0.678
REE-citrate [mg/kg DM]	0^{d}	74^{c}	149^{b}	225^{a}	3.0	< 0.001	< 0.001	0.715
Pure REE [mg/kg DM]	8.0^{d}	18.5^{c}	40.5^{b}	55.3^{a}	0.8	< 0.001	< 0.001	0.016
Pure REE intake [mg/kg LW/d]	0.2^{d}	0.5^{c}	1.1^{b}	1.6^{a}	0.0	< 0.001	< 0.001	0.004

Notes: *Values are given as least square means (LSmeans) and pooled standard errors of means (PSEM)
#Metabolizable Energy
Values with different superscripts within a row are significantly different ($p < 0.05$)

group (A) showed the highest total feed intake but these observed differences were not significant (Table 6). Similar results were observed for the crude protein and metabolizable energy intake. The averaged daily weight gain over all treatment groups amounted to 988 ± 77 g and was in normal ranges for female calves of this age. However, due to reduced feed intake the calves of Group D showed a slightly but not significantly lower daily weight gain than the other groups. The calculated feed-to-gain ratio and ME-to-gain ratio also remained unaffected by the dietary treatments.

4 Discussion

These two experiments were conducted to test whether age and gender play a role regarding efficiency of REE on feed intake and performance parameter. The nutrient composition and energy content of the milk replacer and concentrates, as shown in Table 3 and 4, were comparable between dietary treatments. As already extensively discussed by Schwabe et al. (2011), REE are occurring ubiquitously, therefore they were also detected in roughage and concentrate used in experiment 1 and 2 of the control group.

The health state of calves was not impaired by the REE application as reported by different research groups in feeding experiments with broilers (He et al., 2010) pigs (Förster et al., 2008), calves (Miller, 2006) and fattening bulls (Schwabe et al., 2011), before. In experiment 1, diarrhoea and respiratory diseases were diagnosed and treated, but a relation to REE supplementation was not observed. These diseases are the two most common diseases that occur in young calves.

The birth weight of male calves was higher than that of female calves (data not shown). This result is similar to reports of various authors (Kertz et al., 1997; Junge et al., 2003), who also found verifiable differences of similar magnitude among different gender. For this reason, the male calves were 10.5 % and 8.1 % heavier at the beginning and the end of the first trial (Table 5). With regard to the age of the piglets, some of the preliminary studies suggested, that the effect of performance enhancement of REE is better feasible in newly weaned than in older animals under the optimized conditions of European piglet production (He and Rambeck, 2000; Knebel, 2004; Kraatz et al., 2006). To our knowledge, Meyer et al. (2006) are the sole authors, whom up to now studying the influence of dietary REE supplementation (200 mg REE-citrate/kg milk replacer) on feed intake and performance of female pre-ruminant calves for a period of 6 weeks. Following this study, we used in the experiment 1, the same feed, dose and additives, however with both gender and a higher number of animals. We observed, that the REE treated calves consumed numerically lower concentrate (42 g/d), which mainly resulted from the male calves, however, no interaction between group and sex was observed ($p = 0.291$; Table 5). Furthermore, the supplementation of REE reduced grass hay intake, resulting in lower total DMI in REE group (-7.9 %) versus control group. However, the individual grass hay intake could not be recorded for technical reasons. This finding is supported by the results of the above mentioned authors (Meyer et al., 2006), who also found a decreased total DMI of -7.8 % as a result of reduced hay intake (-44 %), while no differences were observed either in the milk replacer intake (553 g/d in the control group versus 560 g/d) nor in the concentrate intake (156 g/d in the control group versus 161 g/d). In a more recent long-term study with growing bulls Schwabe et al. (2011) reported a significant linear decrease in the grass hay intake from 0.55 to 0.31 kg/d during the growing period (119 to 180 kg LW) as well as in the maize silage intake from 6.09 to 5.44 kg/d during the fattening period (180 to 556 kg LW) after the supplementation of 0, 100, 200 and 300 mg REE-citrate/kg diet. In the present experiment, the increasing REE-citrate supplementation to the diet of growing female calves had no significant effect on the feed intake but a numerally reduction in the feed intake was also detectable (Table 6). The reason for the often observed reduction in the feed intake of cattle, as described above, induced by REE supplementation with the exception of the investigation of Schwabe et al. (2009) is unclear. However, it is well known that REE have many similarities to the element calcium in size, bonding as well as in coordination geometry and donor atom preference which enables them to compete with the calcium ions (Evans, 1990; Redling, 2006). On this basis, it was described that REE can replace calcium ions at superficial membranes sites and prevented calcium ions uptake to less accessible calcium ions sites in smooth muscles and the muscle contraction is thereby inhibited (Weiss and Goodman, 1969; Weiss, 1974; Triggle and Triggle, 1976; Redling, 2006). This in turn can alter the gastrointestinal motility which may decrease the passage rate and therefore affect the feed intake. A second explanation may be an effect on nervous system as feed intake and gastrointestinal motility are controlled via the vegetative nervous system. Since previous studies have demonstrated that lanthanoide showed a variety of actions on nerve cells and most of them are related to the interaction with Ca^{2+} involved transport processes such as inhibition of calcium binding to synaptosomal membranes (Basu et al., 1982) and inhibition of calcium-dependent neurotransmitter release (Przywara et al., 1992). It was also observed that lanthanum can influence the neural release of serotonin (Stefano et al., 1980).

The slightly decrease in feed intake of the REE treated calves was reflected in the live weight gain in both experiments. In experiment 1 the LW gain was 5.5 % and in experiment 2 up to 2.2 % lower compared to the control groups. In contrast, Meyer et al. (2006) observed in spite of a decreased total feed intake a higher average daily LW gain of 14.6 % ($p > 0.05$) in supplemented female pre-ruminant calves. However, our findings are in agreement with Miller (2006), who also found a numerical decrease in LW gain when fattening bulls (83 kg initial LW, an average age of 44 d) were fed with 200 mg REE-citrate/kg over a period of 10 weeks. A recent study by Schwabe et al. (2011) showed similar results, while Schwabe et al. (2009) could even determine a significant decrease in live weight gain of 7 % and an increase in feed-to-gain ratio and ME-to-gain ratio of 10 % when REE-citrate was fed at a concentration of 200 mg/kg DM to fattening bulls in a LW range of 245 to 558 kg. In both experiments of the present study, the feed-to-gain ratio and ME-to-gain ratio were not affected by dietary treatments which indicated that the observed decrease in the weight gain of REE calves could primarily be attributed to reduced voluntary feed intake.

5 Conclusion

In the present feeding trials the use of REE-citrate as feed additive in rations for pre-ruminant and growing calves caused a numerically reduced feed intake, which resulted in a decreased live weight gain.

Based on this inefficiency of REE-citrate under the current experimental conditions it may be concluded that its use as growth promoters in calf diets cannot be recommended.

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References

Basu A, Chakrabarty K, Chatterjee GC (1982) Neurotoxicity of lanthanum chloride in newborn chicks. Toxicol Lett 14:21-25

DLG-Deutsche Landwirtschafts-Gesellschaft (1997) DLG-Futterwerttabellen Wiederkäuer. Frankfurt a M : DLG-Verl, 212 p

Evans CH (1990) Biochemistry of the lanthanides. New York : Plenum Pr, 444 p, Biochemistry of the elements 8

Förster D, Berk A, Hoppen HO, Rambeck WA, Flachowsky G (2008) A note on the effect of rare earth elements on the performance and thyroid hormone status of rearing piglets. J Anim Feed Sci 17:70-74

GfE-Gesellschaft für Ernährungsphysiologie (1991) Leitlinien für die Bestimmung der Verdaulichkeiten von Rohnährstoffen an Wiederkäuern. J Anim Physiol Anim Nutr 65:229-234

GfE-Gesellschaft für Ernährungsphysiologie (2001) Empfehlungen zur Energie- und Nährstoffversorgung der Milchkühe und Aufzuchtrinder 2001. Frankfurt a M : DLG-Verl, 136 p, Energie- und Nährstoffbedarf landwirtschaftlicher Nutztiere 8

He ML, Rambeck WA (2000) Rare earth elements : a new generation of growth promoters for pigs? Arch Anim Nutr 53:323-334

He ML, Ranz D, Rambeck WA (2001) Study on the performance enhancing effect of rare earth elements in growing and fattening pigs. J Anim Physiol Anim Nutr 85:263-270

He ML, Wehr U, Rambeck WA (2010) Effect of low doses of dietary rare earth elements on growth performance of broilers. J Anim Physiol Anim Nutr 94:86-92

Junge W v, Stamer E, Reinsch N, Kalm E (2003) Züchterische Möglichkeiten zur Senkung von Kälberverlusten. Züchtungskunde 75:479-488

Kertz AF, Reutzel LF, Barton BA, Ely RL (1997) Body weight, body condition score, and wither height of prepartum Holstein cows and birth weight and sex of calves by parity : a database and summary. J Dairy Sci 80:525-529

Kessler J (2004) Lanthanoide - Wachstumsförderer mit Zukunft [online]. To be found at <http://www.db-alp.admin.ch/de/publikationen/docs/vortrag_2004_06_22_13.pdf> [quoted 24.07.2012]

Knebel C (2004) Untersuchungen zum Einfluss Seltener Erd-Citrate auf Leistungsparameter beim Schwein und die ruminale Fermentation im künstlichen Pansen (Rusitec). München : Univ, 147 p

Kraatz M, Taras D, Manner K, Simon O (2006) Weaning pig performance and faecal microbiota with and without in-feed addition of rare earth elements. J Anim Physiol Anim Nutr 90:361-368

Meyer U, Spolders M, Rambeck W, Flachowsky G (2006) Effect of dietary rare earth elements on growth performance of preruminant female Holstein calves. Proc Soc Nutr Physiol 15:67

Miller T (2006) Einfluss Seltener Erden in der Schweine- und Kälbermast. München : Univ, 134 p

Przywara D, Bhave S, Bhave A, Chowdhury P, Wakade T, Wakade A (1992) Activation of K+ channels by lanthanum contributes to the block of transmitter release in chick and rat sympathetic neurons. J Membr Biol 125:155-162

Redling K (2006) Rare earth elements in agriculture with emphasis on animal husbandry. München : Univ, 326 p

Schwabe A, Meyer U, Flachowsky G (2009) Effect of dietary rare earth elements (REE) on growth performance of fattening bulls. Proc Soc Nutr Physiol 18:45

Schwabe A, Meyer U, Flachowsky G, Daenicke S (2011) Effect of graded levels of rare earth elements in diets of fattening bulls on growing and slaughtering performance, and on nutrient digestibility of wethers. Arch Anim Nutr 65:55-73

Seibold R, Barth C (1976-1997) Die chemische Untersuchung von Futtermitteln. Melsungen : Neumann-Neudamm, Loseblattsammlung, VDLUFA-Methodenbuch 3

StatSoft Inc (2007) Statistics for Windows™ operating system. Tulsa, OK, USA

Stefano GB, Brogan JJ, Aiello E, Hiripi L (1980) Lanthanum blockade of serotonin release from the branchial nerve of the mussel Mytilus edulis. J Exp Zool 214:21-26

Triggle CR, Triggle DJ (1976) An analysis of the action of cations of the lanthanide series on the mechanical responses of guinea-pig ileal longitudinal muscle. J Physiol 254:39-54

Weiss GB (1974) Cellular pharmacology of lanthanum. Annu Rev Pharmacol 14:343-354

Weiss GB, Goodman FR (1969) Effects of lanthanum on contraction, calcium distribution and Ca45 movements in intestinal smooth muscle. J Pharmacol Exp Ther 169:46-55