

## Bovine *Eimeria* species in Austria

H. Koutny · A. Joachim · A. Tichy · W. Baumgartner

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**Abstract** Bovine eimeriosis is considered to be of considerable importance for the productivity and health of cattle worldwide. Despite the importance of cattle farming in Austria, little is known in this country about the abundance and distribution of bovine *Eimeria* spp. The objective of this study was to obtain detailed information about the occurrence of different *Eimeria* spp. on Austrian dairy farms. Fecal samples from individual calves ( $n=868$ ) from 296 farms all over Austria (82 districts) were collected. Additionally, each farmer was questioned about the occurrence of calf diarrhea, and about the knowledge on coccidiosis and possible control measures. On 97.97% of the investigated farms, calves excreted *Eimeria* oocysts, and 83.67% of the individual samples were positive. After sporulation of positive samples pooled from each farm, 11 *Eimeria* species were found, with *E. bovis* (in 65.54% of the samples and 27.74% of the farms), *E. zuernii* (63.85%/13.86%), *E. auburnensis* (56.76%/13.41%) and *E. ellipsoidalis* (54.05%/14.38%) being the most prevalent,

followed by *E. alabamensis* (45.61%/11.56%), *E. subspherica* (35.14%/5.505%), *E. cylindrica* (33.11%/7.00%), and *E. canadensis* (31.08%/7.74%). *E. wyomingensis*, *E. pellita* and *E. bukidnonensis* were only found sporadically (3.04–4.73% of the samples and 0.16–0.59% of the farms). Mixed infections were present on all farms (2–9 *Eimeria* species/farm). Prevalences by state provinces were high throughout with 77.1–87.9% of the samples and 93.8–100% of the farms. Lower Austria had the highest percentage of positive farms, and Vorarlberg the lowest. Individual OPG (oocysts per gram of feces) values were generally low; 75% of the samples had an OPG of 1,000 or less. The highest detected OPG was 72,400. The mean OPG was 2,525 with above average numbers in Tirol, Carinthia, and Lower Austria. The mean OPG values were significantly positively correlated with the cattle density in the different districts. The majority of the samples were from female Simmenthal calves. Clinical coccidiosis (diarrhea) was observed in 74 cases, and (semi-)liquid diarrhea (56 animals) was significantly correlated with OPG ( $p<0.05$ ). Linear regression on the OPG data showed that OPG values significantly decreased with increasing age of the calves, while the percentage of positive samples increased with age ( $p<0.05$  for both). The term “coccidia” was familiar to 45% of the farmers, and anticoccidial treatment was performed by 13.51% of them, most commonly with toltrazuril. Considering the ubiquitous occurrence and the possible clinical and economic relevance of calf eimeriosis, infections should receive increased attention by both farmers and veterinarians.

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H. Koutny · W. Baumgartner  
Clinic for Ruminants, Department for Farm Animals  
and Veterinary Public Health,  
University of Veterinary Medicine Vienna,  
Veterinärplatz 1,  
1210 Vienna, Austria

A. Joachim (✉)  
Institute for Parasitology, Department for Pathobiology,  
University of Veterinary Medicine Vienna,  
Veterinärplatz 1,  
1210 Vienna, Austria  
e-mail: Anja.Joachim@vetmeduni.ac.at

A. Tichy  
Institute of Population Genetics, Department for Biomedical  
Sciences, University of Veterinary Medicine Vienna,  
Veterinärplatz 1,  
1210 Vienna, Austria

### Introduction

The occurrence of bovine coccidiosis caused by *Eimeria* spp. has been reported worldwide. Of the 21 species that

are known to occur in cattle (Gräfner et al. 1978), 13 have so far been described for Europe (Joyner et al. 1966). Most species are considered to have a low pathogenicity, whereas infection with *E. bovis* or *E. zuernii* may cause severe disease in calves (Supperer 1971; Bürger 1983; Dauschies and Najdrowski 2005). In grazing calves suffering from clinical coccidiosis *E. alabamensis* was reported as the predominant species (Gräfner et al. 1985a; Svensson 2000; von Samson-Himmelstjerna et al. 2006). Clinical coccidiosis is characterized by watery to hemorrhagic diarrhea as the cardinal symptom (Bangoura et al. 2011), sometimes with fibrin and intestinal tissue, abdominal pain, fever, tenesm, dehydration, weakness, anorexia and weight loss (Fanta 1967; Bürger 1983; Dauschies et al. 1986). Usually clinical coccidiosis is a result of the interaction of several factors, including age of the animals, the number of ingested oocysts, production systems and management practices, hygienic conditions, stable temperature, season and the level of stress for the animals, which may favour a clinical outbreak of coccidiosis (Gräfner et al. 1978; Lassen et al. 2009a; Rehman et al. 2011). Generally, clinical coccidiosis is a problem in calves from 3 weeks to 12 months of age (Dauschies and Najdrowski 2005), while in older animals coccidiosis occurs predominantly in a subclinical form, since after repeated contact most animals acquire a protective immunity (Cornelissen et al. 1995). Susceptible calves usually become infected after they are grouped together or moved to a contaminated environment (Hiepe 1978; Joachim 2002). According to Fox (1985), clinical signs are often not demonstrated until 3–8 weeks after initial infection, if at all. Furthermore, Fox (1985) claimed that the observation of one clinical case in a group indicates that oocysts are also cycling in other animals of the group. Although most infected calves appear clinically healthy, subclinical infections may result in reduced feed consumption, malnutrition, impaired growth and weight loss. Infected calves are also more susceptible to secondary diseases, such as pneumonia, bacterial enteritis and viral infections (Fox 1985; Gräfner et al. 1985b). As a consequence, annual economic losses due to both clinical and especially subclinical coccidiosis (Hiepe 1972) were previously estimated to be about US\$ 723 million worldwide (Fitzgerald 1980).

Dairy farming is a major part of the agricultural sector in Austria; however, so far only limited information is available about the prevalence, species composition and the geographic distribution of bovine *Eimeria* infections and their possible impact on animal health and productivity. We therefore conducted an extensive countrywide prevalence study in dairy calves and questioned the farmers with regard to their knowledge on calf coccidiosis and control measures that they carried out.

## Materials and methods

### Sample collection

A total of 868 fecal samples from individual calves from 296 farms in Austria were collected. The farms participating in this study had been selected randomly for each district ( $n=82$ ) with the exception of the city districts of each province state and Vienna. Depending on size, up to four farms in each district were visited once during the observation period (March–October 2010). On each farm, individual samples were collected from two or three randomly selected calves of 3 weeks and older living in groups wherever possible. In most cases samples were taken directly from the rectum, in some cases freshly deposited feces were taken from the ground. Fecal consistency was scored in four categories directly after collection: (1) normal to pasty, (2) semi-fluid to fluid, (3) watery, (4) bloody with or without fibrin or intestinal tissue. Information about previous anticoccidial treatment was documented and each calf was examined for clinical signs of coccidiosis.

Sex, age and breed were documented for calves which were sampled individually.

### Farmer questionnaire

Each farmer was questioned about the occurrence of diarrhea in calves in relation to their age. Additionally they were asked about previous fecal examinations and whether the detected pathogens were known. In particular the owners were asked if the term “coccidia” was known. Previous cases of coccidiosis and management of anticoccidial treatment were recorded.

### Fecal examination

After sedimentation with water samples were concentrated by sucrose–flotation (specific gravity 1.28) and examined microscopically using a 400× magnification for parasitological objects. Oocysts per gram of feces (OPG) were subsequently determined for samples with >100 oocysts counted upon flotation, using a modified McMaster technique with a minimum detection level of 50 OPG. For identification of single *Eimeria* species, oocysts from the remaining material from the McMaster counted samples was isolated for sporulation in 2.5% potassium bichromate solution. After 7–10 days at room temperature, samples were examined under a Nikon Microphot-FXA light microscope at 400× magnification. Samples from the same farm were pooled. The first 100 sporulated oocysts that came into view were measured using the ProgRes CapturePro 2.7 software (Jenoptik AG, Jena, Germany) and determined by morphological appear-

ance of the sporulated oocysts according to Eckert et al. (1995).

### Statistical analysis

All analyses were performed using the statistical software package SPSS® Version 17 (IBM® SPSS® Statistics, IBM Corporation, Somers, NY, USA). Associations between variables were analyzed by using linear regression. Comparative analyses were performed using the Chi-square test and the one-way ANOVA. A value of  $p < 0.05$  was considered significant.

## Results

Oocysts of the genus *Eimeria* were found on 290 farms (97.97%) and in 727 fecal samples (83.67%). In all, 11 *Eimeria* species were determined, with *E. bovis*, *E. zuernii*, *E. auburnensis* and *E. ellipsoidalis* being the most prevalent (Table 1). According to the numbers of oocysts identified in pooled samples, *E. bovis* was also the most abundant species, followed by *E. ellipsoidalis*, *E. zuernii* and *E. auburnensis* (Table 1).

All eight state provinces showed high prevalences on the individual (77.1–87.9%) and farm (93.8–100%) levels (Table 2). Lower Austria had the highest percentage of positive calves, Vorarlberg the lowest. In Salzburg, Styria and Carinthia, all examined farms were positive for *Eimeria* spp., while Vorarlberg, again, had the lowest farm prevalence (Table 2). There were no significant differences between the percentage of positive farms in the eight provinces ( $F=0.728$ ;  $p=0.6$ ). *E. bovis* was the most frequent species on the individual level in each locality, followed by *E.*

**Table 1** Prevalences and intensities of *Eimeria* spp. on the examined farms

<i>Eimeria</i> species	Prevalences (%) on the farms ( $N=296$ sampled farms)	Average proportion (%) in the samples from 290 positive farms
<i>E. bovis</i>	65.54	27.74
<i>E. zuernii</i>	63.85	13.86
<i>E. auburnensis</i>	56.76	13.41
<i>E. ellipsoidalis</i>	54.05	14.38
<i>E. alabamensis</i>	45.61	11.56
<i>E. subspherica</i>	35.14	5.05
<i>E. cylindrica</i>	33.11	7.00
<i>E. canadensis</i>	31.08	5.74
<i>E. wyomingensis</i>	4.73	0.16
<i>E. pellita</i>	4.73	0.50
<i>E. bukidnonensis</i>	3.04	0.59

*zuernii* which was found to be the most prevalent on the farm level in five out of eight state provinces. *E. ellipsoidalis*, *E. auburnensis* and *E. alabamensis* were common, too. *E. subspherica*, *E. cylindrica* and *E. canadensis* were also found in each state province, while *E. wyomingensis*, *E. pellita* and *E. bukidnonensis* were rare. *E. brasiliensis* or *E. illinoisensis* were not found (Table 3).

OPG values were determined for samples with more than ten oocysts per preparation at flotation ( $n=456$ ) and ranged from a minimum of 50 to a maximum of 72,400 OPG. The mean values for the districts of Austria positively correlated with the respective cattle density (Statistik Austria (2009), Vienna ([http://www.statistik.at/web\\_de/statistiken/land\\_und\\_forstwirtschaft/viehbestand\\_tierische\\_erzeugung/index.html](http://www.statistik.at/web_de/statistiken/land_und_forstwirtschaft/viehbestand_tierische_erzeugung/index.html)); Fig. 1). Most calves suffered from a subclinical form of coccidiosis shedding a low number of oocysts; 75% of the samples contained 1,000 OPG or less. Samples with higher values were found more frequently in Tirol, Carinthia, and Lower Austria (Table 4).

The majority of the samples (80.82%) were from female calves. The breeds included in this study belonged in 67.3% to Simmenthal, in 15.4% to Brown Swiss, in 9.8% to Holstein Frisian and in 7.5% to other or mixed breeds. The age of the examined calves ranged from 2 weeks up to 12 months. Linear regression analysis of the OPG values showed a statistically significant decrease in the excretion intensity with increasing age ( $R^2=0.033$ ;  $p=0.031$ ). Concurrently, the number of calves shedding oocysts significantly increased with age ( $R^2=0.025$ ;  $p=0.022$ ).

Mixed infections were present on all farms with positive calves. The number of *Eimeria* species present on the single farms ranged from 2 to 9. In most farms, multiple infections with five species were present.

Diarrhea was observed in 74 calves. A total of 56 samples consisted of (semi-)liquid and 18 samples of watery feces. The OPG values from calves with (semi-)liquid feces were statistically significantly higher than from calves with formed feces ( $p=0.037$ ). However, there was no significant difference in the OPG values between calves with watery feces and calves with normal feces ( $p>0.05$ ). Overall, 25.34% of the farmers declared that they had a problem with diarrhea in calves. The majority of them (68.24%) reported diarrhea mostly in calves at 2–4 weeks of age, 20.27% of the farmers noticed diarrhea in calves in the first week of life. Problems with diarrhea in the fourth to sixth weeks of life was reported by 4.05% of the farmers and 7.43% observed most problems in animals older than 6 weeks.

Most of the farmers (87.50%) stated that the cause of diarrhea in their calves was unknown. In cases where specific diagnostic tests were performed to obtain a diagnosis of the pathogens involved, rotavirus and coronavirus were found most frequently (65.79%), followed by cryptosporidia

**Table 2** Prevalences (%) of *Eimeria* spp. in different state provinces in Austria

Locality	N samples	Prevalence (%)	N farms	Prevalence (%)	Collection period (month)
Vorarlberg	48	77.1	16	93.8	March
Tirol	83	84.3	27	96.3	March
Salzburg	54	83.3	20	100	September
Upper Austria	164	86.6	55	98.2	September–October
Styria	174	79.3	59	100	April–May
Carinthia	93	84.9	35	100	June
Lower Austria	190	87.9	63	96.8	August–September
Burgenland	62	79.0	21	95.2	July
Austria	868	83.8	296	98.0	March–October

(15.79%) and *Eimeria* spp. (13.16%). *Escherichia coli* was determined in 5.26% as the cause of diarrhea in calves.

The term “coccidia” was known to 45% of the farmers; 13.51% treated regularly for coccidiosis. In most of these cases (67.5%), only individual calves had been treated. Metaphylactic treatment of calves was only carried out by 2.36% of the farmers. In the majority of cases (55%) toltrazuril (Baycox® Bovis, 50 mg/ml suspension) was used for coccidiosis treatment, followed by diclazuril (Vecoxan®, 2.5 mg/ml suspension) and sulfonamide–trimethoprim combinations (15% each). In the remaining cases the applied medication was not known. Metaphylaxis was carried out with Baycox® Bovis (71%) or Vecoxan® (29%).

## Discussion

First records on the occurrence of bovine coccidiosis were made by Zürn in 1878 (Supperer 1952). Currently, coccidiosis is estimated to be one of the most frequently occurring parasitic infections in cattle (Jäger et al. 2005) with a prevalence of up to 100% in calves (Gräfner et al. 1982; Fox 1985; Cornelissen et al. 1995).

Earlier, mostly anecdotal, studies already described the occurrence of different *Eimeria* species in cattle in Austria. Supperer (1952) investigated fecal samples from 130 calves and young cattle aged between 2 months and 2 years and reported a prevalence of 73.18% for *Eimeria* with a total of seven species including the first description of *E. pellita* as a new species and the first finding of *E. auburnensis* in Europe. He also described *E. boehmi* as a new species which was, however, later identified as *E. brasiliensis* Torres and Romaos 1939. Sahliger (1977) examined 225 samples from a small area of Austria (districts of Horn and Mürzzuschlag) and determined a prevalence of 67.55% for bovine eimeriae with a total of eight species involved. Fanta (1967) described the clinical signs observed in Austrian calves infected with coccidia and the differences in the occurrence of *Eimeria* infections in older calves kept on pasture and in younger calves kept indoors. He particularly emphasized the increase of

severe clinical cases of coccidiosis he noticed in young calves kept in stables.

The aim of the present study was to obtain up-to-date data on the prevalence and importance of *Eimeria* infections in dairy calves in different regions of Austria. To make a meaningful statement, 296 farms from geographically defined locations were investigated in eight state provinces of Austria (82 districts). The result of the study showed clearly that *Eimeria* infections are very common amongst cattle farms all over Austria; 97.97% of the examined farms and 83.67% of all samples were positive. A total of 11 *Eimeria* species could be identified by their morphological appearance: *E. bovis*, *E. ellipsoidalis*, *E. zuernii*, *E. auburnensis*, *E. alabamensis*, *E. cylindrica*, *E. canadensis*, *E. subspherica*, *E. pellita*, *E. wyomingensis*, *E. bukidnonensis*. Compared to the findings of Supperer (1952) and Sahliger (1977), these results represent on the one hand an increase of the number of species found in Austria and on the other hand also indicate an increase in the prevalence of these infections. The finding that coccidiosis is on the increase has also been reported from other authors (Klockiewicz et al. 2007; Stewart et al. 2008; Rehman et al. 2011).

## Biodiversity

Since the prevalence of the different species may vary considerably due factors like region (Niilo 1970), season (Gräfner et al. 1985b), age, or housing conditions (Joyner et al. 1966; Eller 1991; Faber 2000; Dausgies and Najdrowski 2005), varying prevalences of *Eimeria* spp. were expected. However, the distribution of individual *Eimeria* species in Austria showed no obvious differences regarding the occurrence in the various state provinces.

According to Ernst et al. (1987), infections with *E. bukidnonensis*, *E. wyomingensis* and *E. pellita* are only rarely observed. These species were reported with a low prevalence from several countries (Sahliger 1977; Ernst et al. 1987; Cornelissen et al. 1995; Matjila and Penzhorn 2002; Cicek et al. 2007; Farkas et al. 2007). In this study,



**Table 3** Occurrence of *Eimeria* species in different state provinces of Austria (% prevalence)

	Salzburg		Tirol		Salzburg		Upper Austria		Styria		Carinthia		Lower Austria		Burgenland	
	Samples	Farms	Samples	Farms	Samples	Farms	Samples	Farms	Samples	Farms	Samples	Farms	Samples	Farms	Samples	Farms
<i>E. subspherica</i>	3.93	37.50	3.15	29.63	4.20	55.00	3.38	36.36	5.09	32.20	4.72	34.29	7.11	33.33	9.67	33.33
<i>E. zuernii</i>	18.16	<b>75.00</b>	19.00	<b>70.37</b>	15.87	<b>65.00</b>	18.83	<b>78.18</b>	12.75	<b>59.32</b>	9.97	42.86	13.23	68.25	5.00	47.62
<i>E. ellipsoidalis</i>	17.49	50.00	13.55	59.26	11.27	65.00	17.65	58.18	18.45	55.93	14.99	42.86	12.60	50.79	5.67	57.14
<i>E. cylindrica</i>	2.93	25.00	11.85	44.44	6.47	30.00	9.48	32.73	8.95	37.29	1.00	17.14	7.11	33.33	3.67	47.62
<i>E. alabamensis</i>	5.02	43.75	6.75	37.04	11.53	45.00	11.60	41.82	11.05	44.07	15.94	40.00	12.81	53.97	18.53	57.14
<i>E. bovis</i>	<b>23.60</b>	<b>75.00</b>	<b>23.10</b>	62.96	<b>31.87</b>	60.00	<b>28.68</b>	74.55	<b>22.05</b>	52.54	<b>35.88</b>	<b>62.86</b>	<b>30.87</b>	<b>73.02</b>	<b>36.47</b>	<b>66.67</b>
<i>E. canadensis</i>	9.46	50.00	4.25	37.04	4.80	30.00	5.35	38.18	7.64	35.59	8.88	31.43	2.40	14.29	8.73	23.81
<i>E. wyomingensis</i>	0.00	0.00	0.30	7.41	0.00	0.00	0.13	1.82	0.14	3.39	0.22	11.43	0.21	4.76	0.27	9.52
<i>E. auburnensis</i>	14.98	56.25	17.55	66.67	14.00	55.00	1.65	69.09	13.20	57.63	7.84	40.00	13.51	50.79	12.00	57.14
<i>E. pellita</i>	4.44	12.50	0.40	7.41	0.00	0.00	0.38	5.45	0.66	11.86	0.00	0.00	0.15	1.59	0.00	0.00
<i>E. bukidnonensis</i>	0.00	0.00	0.10	3.70	0.00	0.00	2.90	7.27	0.02	1.69	0.56	8.57	0.00	0.00	0.00	0.00

Data in bold indicate the most frequent species in each state province. For sample distribution, see Table 2

these species were found sporadically and not in all state provinces. The oocysts of *E. subspherica*, *E. cylindrica* and *E. canadensis*, on the other hand, were detected regularly all over Austria, although always with a low abundance.

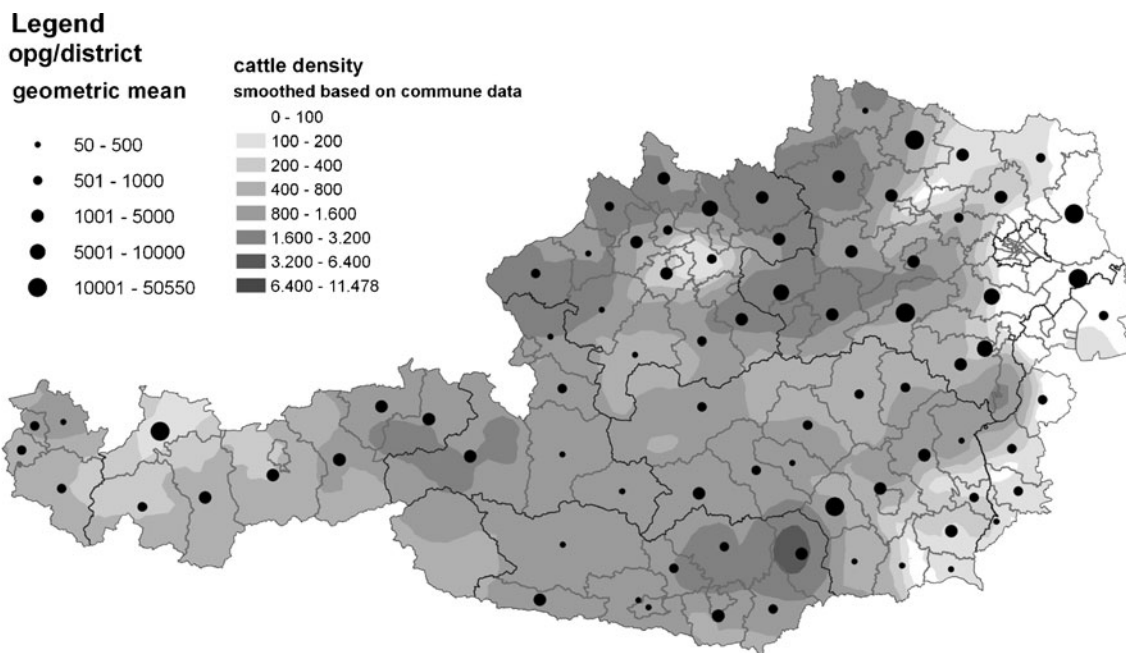
The most frequently found *Eimeria* species are generally *E. bovis*, *E. ellipsoidalis*, *E. zuernii* and *E. auburnensis* (Ernst et al. 1987; Weinandy 1989; Matjila and Penzhorn 2002; Farkas et al. 2007; Lassen et al. 2009b), which was confirmed by the present study. According to Hiepe (1983), these species have the highest reproductive potential, which may be the reason for their frequent occurrence. In accordance with Ernst and coauthors (1984) and Weinandy (1989), *E. bovis* was found to be the most prevalent species. Interestingly, samples collected in Carinthia, Salzburg, Burgenland, and Lower and Upper Austria showed a considerably higher prevalence of *E. alabamensis* compared to the rest of Austria. *E. alabamensis* is the predominating species in calves on pasture (Svensson 2000; von Samson-Himmelstjerna et al. 2006), and can also be transmitted via contaminated hay (Svensson 1997). This increase could be explained with the sampling season rather than the geographic region. In the mentioned provinces, samples were collected during the grazing season (June to October). Although Supperer (1952) and Sahliger (1977) reported the occurrence of *E. brasiliensis* in Austria, oocysts of this species were not found in this study. *E. illinoisensis* seems to be absent from Austria as it has never been reported and could not be provided in the present study.

Positive samples from single farms were pooled for species identification because it was assumed that farms are the units where *Eimeria* species are distributed equally. Calves seemed to suffer from multiple infections since monospecific samples were never found.

Coccidiosis is a problem particularly of confined animals and since intensive animal husbandry practices increase the risk of coccidiosis (Fox 1978; Matjila and Penzhorn 2002) OPG values were expected to be higher in regions with a high density of cattle and specifically in areas with large herd sizes (Klockiewicz et al. 2007; Stewart et al. 2008). Dairy cattle husbandry in Austria has an old tradition and important cultural significance. It is mainly maintained in smallholder systems with an average of 10–19 dairy cattle per farm (Grohsebner 2010). Only 0.5% of the farms have a stock greater than 100 dairy cattle. Due to the small herd sizes the density of animals is generally low, and this may result in low-level infections with subsequently moderate oocyst shedding despite the high prevalence rates.

### Epizootiology

A significant association between season and the prevalence of *Eimeria* spp. was reported previously (Dauguschies and



**Fig. 1** Mean values for each district all over Austria in correlation with the local cattle density

Najdrowski 2005; Stewart et al. 2008). However, the season with the highest prevalence rates vary in different studies. Stewart and coauthors (2008) found a significantly higher prevalence of *Eimeria* infections during autumn, while Dauschies and Najdrowski (2005) indicated an increase in the prevalence of *Eimeria* infections during spring. Other authors reported about a significant increase of coccidiosis during the period of wet season in warmer climates (Rehman et al. 2011). According to Weinandy (1989) the influence of the climatic conditions on the prevalence of *Eimeria* spp. is not always clearly demonstratable. The highest mean OPG levels were found in Lower Austria and Tirol. These regions differ greatly geographically and climatically. Samples from Tirol (alpine area, 467–3,797 m

above sea level) were collected in March when frost was still present while samples from Lower Austria (lowland to pre-alpine area, 139–2,075 m above sea level) were collected between September and October under sunny conditions. The influence of season vs. geography is therefore not separable.

This study shows that infections with *Eimeria* spp. are ubiquitous in Austrian dairy cattle at an age of 3 weeks up to 1 year. However, the various factors that may influence the prevalence and intensities, such as farm factors including hygiene, management practices or housing systems, and geographical and climatic conditions cannot be separated and attributed to varying prevalences in the different areas.

**Table 4** Percentages of samples within a specific OPG range for the state provinces of Austria

	OPG range (% of positive samples)			N McMaster-countable samples	Mean OPG ( $\pm$ SD)
	50–1,000	1,001–10,000	10,001–100,000		
Vorarlberg	86.36	13.64	0.00	22	625 ( $\pm$ 1,669)
Tirol	57.50	32.50	10.00	40	4,253 ( $\pm$ 15,016)
Salzburg	91.67	4.17	4.17	24	1,533 ( $\pm$ 6,681)
Upper Austria	78.35	17.53	4.12	97	1,850 ( $\pm$ 7,673)
Styria	84.27	12.36	3.37	89	1,616 ( $\pm$ 7,149)
Carinthia	75.51	14.29	10.20	49	2,186 ( $\pm$ 6,390)
Lower Austria	59.43	26.42	14.15	106	4,598 ( $\pm$ 15,315)
Burgenland	89.66	10.34	0.00	29	441 ( $\pm$ 746)
Austria	74.78	18.20	7.02	456	2,525 ( $\pm$ 10,248)

For sample distribution, see Table 2

### Correlations between OPG levels, age and clinical signs

OPG levels can vary considerably in different animals during the course of infection (Staschen 2009), so a single individual sample may not accurately reflect the overall level of oocyst excretion. However, the OPG levels were generally low on average. In many epidemiological studies about bovine coccidiosis clinical cases have been reported rarely or not at all (Cornelissen et al. 1995; Matjila and Penzhorn 2002; Cicek et al. 2007). It can be assumed that coccidiosis mostly occurs in a subclinical form. In the present study, clinical coccidiosis with the main feature of diarrhea was observed in 74 cases (8.5%). There was a significant difference in the average OPG values between calves with formed feces and calves with semi-fluid to fluid feces. However, OPG values from calves suffering from watery diarrhea were not significantly higher than those from calves appearing healthy. Dauschies and Najdrowski (2005) also reported that the amount of oocysts shed is not closely correlated to the severity of coccidiosis. In contrast, Bangoura and Dauschies (2007) found a positive correlation between quantified oocyst excretion and fecal consistency in an experimental *E. zuernii* infection in calves. They also mentioned that the infection dose has a marked influence on the extent of clinical symptoms. Furthermore, a significant reduction of the OPG level with increasing age of the calves was seen, which was also reported by other authors (Cornelissen et al. 1995; Matjila and Penzhorn 2002; Cicek et al. 2007; Rehman et al. 2011) and can be explained with the development of protective immunity due to previous contact with the parasite (Senger et al. 1959; Fitzgerald 1967; Dauschies et al. 1986). By contrast, the percentage of *Eimeria*-positive animals increased with increasing age of the calves. These two findings lead to the conclusion that on the one hand young calves are able to develop a sufficient immune response to avoid a clinical outbreak of coccidiosis after reinfection; on the other hand, this protective immunity is not able to displace the pathogen completely. It therefore has to be considered that older, clinically healthy, immune animals may be responsible for the distribution of oocysts and that these may lead to heavy outbreaks of clinical coccidiosis in susceptible individuals (Gräfner et al. 1985b).

### Consultation with the farmers

The statements of the farmers about the occurrence of diarrhea in calves showed clearly that the majority of them were not familiar with the possible impact of coccidiosis on animal health. This is also reflected in the low number of farmers who already performed anticoccidial treatment. On the other hand, this may be due to the fact that coccidiosis usually occurs in a subclinical form. Only in very few cases

metaphylactic treatment was performed to reduce the prevalence of coccidiosis, and as with therapeutic treatment it was usually only applied to individual calves. Sporadic treatment, however, is not recommended since it does not efficiently reduce the environmental contamination with oocysts and thus the risk of parasite transmission (Bangoura et al. 2007). According to Staschen (2009), prerequisites for determining the time point for treatment is a precise diagnosis and an insufficient understanding of the specific epidemiological conditions within a livestock operation. These findings underline how important it is to familiarize farmers and veterinarians with the possible economic impact of bovine coccidiosis. Interestingly, Bangoura et al. (2011) reported a similar situation about the awareness of bovine coccidiosis in Germany. Although their results showed clearly that coccidiosis must be considered as a ubiquitous problem in Germany in shed-raised calves which affects almost all examined facilities to varying degrees, regardless of size, comparatively few farms established targeted control strategies. The economic losses due coccidiosis, especially subclinical coccidiosis (Fitzgerald 1980; Fox 1985), should be a motivation to introduce special hygienic measures and metaphylactic medication on affected cattle farms to establish and maintain a healthy livestock. Frequently, educational work by the veterinarians about the impact of coccidiosis and its prevention is necessary to establish an effective control regime. The efficacy of toltrazuril against infections with *Eimeria* spp. was shown in various studies (Bohrmann 1991; Mundt et al. 2003, 2005; Epe et al. 2005; Jonsson et al. 2011). The additional costs for treatment are justified for all farms with a diagnosed problem of coccidiosis and for farmers who are focused on raising profitable and healthy dairy calves for progeny. According to Fox (1978), a calf which suffered from a clinical form of coccidiosis will never become profitable. A long-term survey about dairy calves affected by clinical coccidiosis and their future development of fertility and milk yield would be of interest to investigate the actual effect of coccidiosis.

In conclusion, it could be shown that *Eimeria* spp., especially the pathogenic species *E. bovis* and *E. zuernii*, are prevalent in Austrian dairy herds, causing mostly subclinical infections. Taking into consideration the economic importance of bovine coccidiosis and the possibility of severe outbreaks especially on larger farms and in areas with higher cattle density, surveying and controlling the infection should receive an increased awareness.

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