Effect of dietary supplementation with preparation comprising the blend of essential oil from *Origanum vulgare* (lamiaceae) and *Citrus* spp. (citraceae) on coccidia invasion and lamb growth

Paulina Dudko\(^a\), Andrzej Junkuszew\(^a\), Wiktor Bojara\(^b\), Michal Milerskib, Klaudiusz Szczepaniak\(^c\), Joël Le Scouarnecd, Jitka Schmidov\(^a\), Krzysztof Tomczuk\(^c\) and Maciej Grzybek\(^c\)

\(^a\)Department of Small Ruminants Breeding and Agriculture Advisory, University of Life Sciences in Lublin, Poland; \(^b\)Institute of Animal Science, Prague, Czech Republic; \(^c\)Department of Parasitology and Invasive Diseases, University of Life Sciences in Lublin, Poland; \(^d\)NEOVIA Research and Development Division, Vannes Cedex, France

**ABSTRACT**

The objective of this research was to assess the effectiveness of dietary supplementation with oils extracted from *Origanum vulgare* (Lamiaceae) and *Citrus* spp. (Citraceae) against coccidia and to determine the impact on lamb growth in an indoor housing system. A total of 222 ewes and 276 lambs of the Polish Lowland Sheep breed maintained indoors under the same environmental conditions were included in the study. Four-month pregnant ewes were divided into three treatment groups following parasitological evaluation. Experimental diets were supplemented with containing vegetal extracts of *O. vulgare* and *Citrus* spp. During the study, parasitological analyses and assessments of lamb growth were conducted. *In vivo* evaluation of lamb muscularity and fatness was performed at 100 days of age. The inclusion of the preparation containing the essential oil blend of *O. vulgare* and *Citrus* spp. in the diet of sheep resulted in decreases in both the intensity and prevalence of coccidian infection within the flock as well had influence increases in lamb growth. Therefore, this dietary supplement may contribute to the improved profitability of sheep farming through increased production efficiency and the production of higher-quality meat.

**ARTICLE HISTORY**

Received 5 January 2017
Revised 27 February 2017
Accepted 14 March 2017

**KEYWORDS**

Lamb; *Eimeria* spp.; coccidiosis; essential oil; lamb growth

**INTRODUCTION**

Parasitic invasions are ranked among the most important barriers to efficient sheep production, posing serious hazards to flock health, especially at the high stocking densities that are commonly encountered in sheep farming (Ndao et al. 1995; Perry & Randolph 1999). The threat of parasitic infection in sheep housing facilities is a result of continual contamination of the animal environment with invasive parasites. The occurrence of parasitic infections commonly leads to adverse health consequences in animals, what cause significant losses in agriculture (Prichard 1994). An underestimated problem of an infected flock are subclinical infection which associated with diminished animal performance and profitability (Gauly et al. 2004; Mandal et al. 2007; Junkuszew et al. 2015; Grzybek et al. 2016). As a subclinical parasitic invasion proceeds asymptptomatically, it often goes unnoticed by sheep producers and is simply neglected. Conventional infection-control measures rely on the application of chemical agents. The repeated use of antiparasitic drugs may induce the development of parasite resistance that reduces therapeutic efficacy (Kaplan 2004; Waller 1997). Therefore, the chance to improve the profitability of animal production are use of efficient prophylactic strategies based on substances of plant origin to maintain low rates of infection (Athanasiadou & Kyriazakis 2004; Geary et al. 2004; Junkuszew et al. 2015). For example, the positive effect on reducing coccidiosis and increases in lamb growth in the application of essential oils from *Thymus vulgaris*, *Allium sativum*, *Artemisia absinthium*, *Dryopteris filix-mas*, *Tanacetum vulgare*, *Cucurbita pepo*, *Chenopodium ambrosioides*, *Inula helenium*, *Peumus boldus*, *Corallina rubens* has been previously reported (Junkuszew et al. 2015).

The main hazard for lambs in indoor housing systems seems to be coccidial infection, which results from the contamination of the indoor environment...
with oocysts excreted in the faeces of ewes. Importantly, the course of coccidian invasion is dependent on a number of factors. In addition to the intensity of the invasion, individual host characteristics play a great role and the specific and non-specific immune status of the animal is crucial (Klockiewicz et al. 2007; Tomczuk et al. 2015). Not infrequently, animals with a coccidian infection do not show any clinical manifestations and the parasitic disease symptoms occur when the animal body condition is deteriorating which is connected with the animal immunity system suppression (Binns et al. 2002). The apparent absence of disease during chronic coccidian infection can adversely affect the normal bacterial flora of the gastrointestinal tract and damage the mucosal lining of the intestine. This injury leads to impaired absorption of nutrients and decreased body weight gains (Daugschies et al. 2007; Chartier & Paraud 2012). In the light of these facts, it would be beneficial to study and introduce parasite prevention programmes using natural vegetal material that could help alleviate the course of *Eimeria* spp. invasion, limit subclinical coccidiosis and increase daily weight gain in sheep (Junkuszew et al. 2015).

Taking into consideration drug resistance occurring worldwide, the costs of synthetic anthelmintics and the potential of natural medicines, the objectives of this study were to assess the activity and spectrum of a preparation made from *Origanum vulgare* (Lamiaceae) and *Citrus* spp. (Citraceae) extracts against coccidial infection and to determine the impact of this extract on the growth of lambs maintained in an indoor housing system.

**Materials and methods**

**Study location**

This study was conducted at the research experimental station in Bezek, part of the University of Life Sciences in Lublin, located in south-eastern Poland (51.197498 N 23.256301 E). The farm housed 550 ewes in the combined indoor-pasture management system. Lambing took place in January and lambs were kept with mothers throughout the entire experiment period.

**Animals**

The research animals included 222 ewes and 276 lambs of the Polish Lowland sheep breed. During the trial period, the animals were housed indoors under the same environmental conditions.

**Trial groups**

On the basis of coproscopic examination for parasite infection performed, ewes were randomised into three experimental groups in which this initial incidence and intensity of parasite infection were similar (Table 1). Ewes in all groups were uniform in terms of genetic background, age and housing conditions. Groups were kept separately from the 4th month of pregnancy. Experimental diets were formulated to contain the OILIS SD dietary supplement (NEOVIA/France), at the dose 4 g/day (for ewes) and 2 g/day (for lambs). According to the information provided by the producer, OILIS SD contained a blend of specific natural vegetal extracts from *O. vulgare* and *Citrus* spp. OILIS SD is a solid (free flowing powder). Contained in the preparation oils are stable and therefore to avoid problems and make it easier to distribute was mixed with barley once before distribution. The basic feeding system was the same in all of the treatment groups. Detailed feed composition in each experimental group presented in Tables 2 and 3.

Group 1 (74 ewes and 87 lambs) was the control group, which diet was not supplemented by OILIS SD during the duration of the experiment.

Group 2 (74 ewes and 105 lambs) ewes were fed with a diet supplemented with OILIS SD from the 4th month of pregnancy until lambing. After lambing, ewes and their lambs were fed the same diet as in Group 1.

Group 3 (74 ewes and 84 lambs) ewes were fed with a diet supplemented with OILIS SD from the 4th month of pregnancy until lamb weaning.

### Table 1. Prevalence (Prev., %) and intensity (Int.) of parasite invasion in ewes before the beginning to the experiment.

|               | Group 1                        | Group 2                        | Group 3                        |
|---------------|--------------------------------|--------------------------------|--------------------------------|
|               | Intensity (Log)                | Intensity (Log)                | Intensity (Log)                |
|               | Prev. (%) X ± SE Max           | Prev. (%) X ± SE Max           | Prev. (%) X ± SE Max           |
| *Eimeria* spp.| 22.94 0.310 ± 0.081 300        | 21.46 0.327 ± 0.080 200        | 19.98 0.133 ± 0.056 200        |
| Gastrointestinal nematodes | 13.32 0.155 ± 0.059 200 | 13.32 0.155 ± 0.057 100 | 11.84 0.169 ± 0.061 200 |
| *Trichuris*   | 0.90 ± 0.000 ± 0.000 200       | 4.44 0.052 ± 0.034 100         | 4.44 0.057 ± 0.039 200         |
| *Capillaria*  | 8.88 0.103 ± 0.047 100         | 0.70 ± 0.000 ± 0.000 200       | 3.7 0.000 ± 0.000 100          |

P. DUDKO ET AL.
Newborn lambs were fed with a diet supplemented with OILIS SD from 14 days after birth to slaughter. The study included ewes that lambed within 14 successive days and their offspring.

**Coproscopic examination**

Parasitological analyses were performed throughout the experiment to identify gastrointestinal parasites in ewes and lambs in the three treatment groups. The first faecal collection and analysis of ewes was performed two months before lambing and these results served as the basis for animal allocation into treatment groups. Faecal samples were collected from lambs at 28, 42, 56, and 70 days of age. Faecal samples were taken directly from the rectum of ewes or lambs. Flotation method with saturated sodium chloride and sucrose was then used (specific gravity 1.25 g/ml) (Dryden et al. 2005). To determine the actual parasite burden, OPG (oocysts per gram of faeces) and EPG (eggs per gram of faeces) were calculated using the McMaster method according to the Raynaud modification (Raynaud 1970; Kochanowski et al. 2013).

**Lamb growth**

All lambs included in the study were born within 14 successive days. Newborn lambs were weighed at birth and at 28, 56, 70 and 100 days of age. Lamb weights were used to calculate daily body weight gains between the sampling times. *In vivo* ultrasound measurements of eye-muscle depth and subcutaneous fat-layer thickness were done in 100-day-old lambs using an ultrasound scanner (EchoSon Albit) equipped with electronic broadband linear probe (LA-510/L40). The ultrasonic measurements were performed between the last thoracic vertebra and the first lumbar vertebra.

**Statistical analysis**

Prior to analysis, oocyst counts were converted into natural logarithms (log [OPG +1]).

Data were analysed using multifactor analysis of variance (factorial ANOVA with interaction), Statistica programme (data analysis software system), version 6 (StatSoftInc., 2003). The analysis was conducted according to the mathematical model:

\[ Y_{ijk} = l + G_i + S_j + T_k + (G_i/C3)S_j + (G_i/C3)T_k + (S_j/C3)T_k + e_{ijk} \]

where:
- \( Y_{ijk} \) – level of analysed trait
- \( l \) – mean trait value for population
- \( G_i \) – fixed effect of animal belonging to experimental group (Group 1, Group 2, Group 3)
- \( S_j \) – fixed effect of gender (ram, ewe)
- \( T_k \) – fixed effect of birth type (single, twins)
- \( (G_i/C3)S_j \) – interaction of experimental group and gender

### Table 2. Diet composition during the experiment (Groups without supplementation).

|                | Group 1  | Group 2  | Group 3  |
|----------------|----------|----------|----------|
|                | December | January  | February | March     | April     |
|                | Ewes     | Lambs    | Ewes     | Lambs    | Ewes     | Lambs   |
| Barley         | 0.1      | 0.1      | 0.1      | 0.05     | 0.1      | 0.05    |
| Crushed oats   | 0.2      | 0.4      | 0.4      | 0.03     | 0.4      | 0.25    |
| Bran           |          |          | 0.03     |          |          |         |
| Dried sugar beet pulp | 0.03 | 0.05     | 0.05     |          | 0.05     |         |
| Rape extracted meal |          |          |          |          |          |         |
| Soybean meal   |          |          |          |          |          |         |
| Hay            | 0.8      | 0.8      | 0.8      | 0.1      | 0.8      | 0.2     |
| Green silage   | 2.0      | 2.5      | 2.5      | 2.5      | 2.5      | 0.8     |

### Table 3. Diet composition during the experiment (Groups with supplementation).

|                | Group 2 + Group 3 | Group 3  |
|----------------|-------------------|----------|
|                | December | January | February | March     | April     |
|                | Ewes     | Lambs   | Ewes     | Lambs    | Ewes     | Lambs   |
| Oilis Feed*    | 0.1      | 0.1      | 0.1      | 0.1      | 0.1      | 0.1     |
| Crushed oats   | 0.2      | 0.4      | 0.4      | 0.03     | 0.4      | 0.25    |
| Bran           |          |          | 0.03     |          | 0.2      |         |
| Dried sugar beet pulp | 0.03 | 0.05     | 0.05     |          | 0.05     |         |
| Rape extracted meal |          |          |          |          |          |         |
| Soybean meal   |          |          |          |          |          |         |
| Hay            | 0.8      | 0.8      | 0.8      | 0.1      | 0.8      | 0.2     |
| Green silage   | 2.0      | 2.5      | 2.5      | 2.5      | 2.5      | 0.8     |

*Oilis Feed (Barley 96% + 4 % Oilis SD)
(G*T) – interaction of experimental group and birth type
(S*T) – interaction of gender and birth type
eijk – random error

Tukey’s test (for different numbers) at $p \leq 0.05$ and $p \leq 0.01$ was used to determine significance of differences among group means.

The chi-square test was used to determine the significance of differences in prevalence. The data were analysed using the programme ‘R’, module ‘epir’ (Stevenson & Heuer 2012).

Results

The coproscopic evaluation prior to the beginning of the trial revealed the predominant presence of protozoa from the *Eimeria* genus, gastrointestinal nematodes, and nematodes of the *Capillaria* genus in the ewe flock (Table 1). Parasitic invasion intensity and prevalence were similarly low in all experimental groups and no clinical manifestations. Not found in any case, significant differences of statistical.

The coproscopic examination of lambs conducted at 28, 42, 56 and 70 days of age detected only presence of oocysts from the *Eimeria* genus. At 28 days of age, the prevalence of *Eimeria* spp. oocysts ranged between 6.67% in Group 2 up to 29.89% in Group 1 (Figure 1). The difference was statistically significant ($p \leq 0.01$). Invasion intensity (Figure 2) was lowest in Group 2 (mean log OPG - 0.095) and highest in Group 1 (mean log OPG 0.731). After 42 days, the prevalence of *Eimeria* spp. oocysts increased by 9.19, 43.81 and 47.62 percentage points in Groups 1, 2 and 3, respectively. The difference between Group 1 and 2 was statistically significant ($p \leq 0.01$).

The highest invasion intensity ($p \leq 0.01$) at 42 days of age was reported in Group 3 (mean log OPG – 2.439), compared to was observed in Group 1 (mean log OPG – 0.745) and Group 2 (mean log OPG – 0.789). On the next sampling day (56 days), a decline in the prevalence of *Eimeria* spp. oocysts was observed in the group fed with the supplemented diet (Group 3 = 46.43%), while the prevalence continued to increase in the other two groups (Group 1 = 80.46 and Group 2 = 67.62%). The differences between Group 3 and Group 1 was statistically significant ($p \leq 0.01$).

Similarly, invasion intensity was highest ($p \leq 0.01$) in Group 1 (mean log OPG 2.283), while the lowest intensity was observed in Group 2 (mean log OPG 1.107) and Group 3 (mean log OPG – 1.071). A similar trend in both invasion intensity and prevalence was observed at 70 days of age. It is noteworthy that the invasion prevalence in the group of lambs fed supplemented diet with essential oil from *Origanum vulgare* and *Citrus* spp. (Group 3 – 42.86%) was less ($p \leq 0.01$) than of that observed in Group 1 – 96.55% and Group 2 – 90.48%. The intensity of invasion *Eimeria* spp. was statistically the lowest ($p \leq 0.01$) in the Group 3 in compared to Group 1 and 2 (Figure 2).

No significant differences were observed in the body weight of lambs at birth or at 28 days of age between the experimental groups (Table 4). Lamb weights at 56 days of age indicated that the animals from Group 3 were significantly heavier than the
lambs in Group 1 and Group 2 \((p \leq .01)\). At 70 and 100 days of age, lambs from Group 3 continued to be significantly heavier than lambs from the other two groups \((p \leq .01)\). No differences in lamb weight were observed between Group 1 and Group 2 throughout the experiment.

The positive impact of the coccidiostatic additive was confirmed by the calculated daily weight gains between the sampling dates (Table 5). Notably, during the period from 28 to 56 and 0 to 100 days of age, lamb daily weight gains in Group 3 were significantly higher than in the other groups \((p \leq .01)\). During the other experimental periods, the calculated daily weight gains were also higher in Group 3 than in Groups 1 and 2.

Ultrasound scanning was performed to determine the effect of the coccidiostatic preparation on lamb muscularity and adiposity (Figure 3). The thinnest layer of fat tissue was observed in Group 3 \((3.20 \text{ mm})\) when compared to the other two groups (Group
1 = 4.23 mm and Group 2 = 3.85 mm). The average depth of the longissimus dorsi muscle was significantly higher in Group 3 (25.78 mm) than in the other two groups (Group 1 = 22.21 mm and Group 2 = 22.33 mm) (p < .01).

Discussion

The assessment of the effectiveness of antiparasitic treatments should consider not only the treatment dose, but also the optimal timing of application. The present study aimed to establish if a coccidiostatic preparation formulated with essential oils from O. vulgaris and Citrus spp. administered to pregnant ewes could decrease the prevalence and intensity of protozoan (Eimeria spp.) invasion and thus, reduce the risk of environmental contamination with oocysts. As is generally known, coccidiosis resulting from environmental exposure to oocysts poses a serious threat to nursing lambs (Junkuszew et al. 2015). It should be noted that both the prevalence and intensity of protozoan invasion by Eimeria spp. was relatively low in the ewe flock at the beginning of the current study. However, ewes supplied with the evaluated dietary supplement during pregnancy yielded lambs that were characterised by a lower intensity and prevalence of coccidian invasion in lambs at 28 days of age compared to lambs from the control group. These results indicate a lower risk of lamb infection that is related to a lowered environmental contamination with oocysts in the groups receiving the OILIS SD dietary supplement during gestation. Interestingly, the highest increase in the prevalence and intensity of invasion occurred at 42 days of age in lambs from Group 3 that received the supplemented diet. It was previously demonstrated that 42 days of age is within the period when invasion intensity increases to a peak (Junkuszew et al. 2015). The higher intensity of invasion in Group 2 and 3 may be attributed to the activity of the preparation applied in the pregnancy. Lambs whose mothers were supplied with the coccidiostatic dietary supplement during pregnancy may also have a compromised resistance against coccidian invasion, which would favour an increase in the prevalence and intensity of invasion. Pregnant ewes are known to produce antibodies, which are passed to their offspring via the colostrum. Accordingly, a lower level of coccidia during pregnancy in ewes receiving the supplemented diet could lead to a lack of stimulation of the immune system leading to a decrease in the production of specific antibodies. The substantial effects of ewes milk on lamb body weight and immune status has been confirmed in other studies (Hernández-Castellano et al. 2015). Another factor resulting in the increased prevalence and intensity of invasion in Group 3 may be associated with the activity of the examined dietary supplement promoting a higher rate of oocyst excretion. Key information to consider when interpreting the results of the current study is that lambs were offered supplemented creep feed beginning at 14 days of age; however, observations of lamb behaviour throughout the nursing period revealed that lambs only began showing a genuine interest in consuming solids at approximately 20 days of age. Until then, the main food for lambs is mother’s milk. Probably as well this is the reason later infect lambs...
coccidia. In addition, the average prepatent period for coccidian oocyst excretion is two to three weeks (Le Sueur et al. 2009), which may have contributed to the increased invasion prevalence and intensity of *Eimeria* spp. invasion in the lambs fed a diet containing this supplement. This effect may be attributed to the composition of the essential oils of *O. vulgare* and *Citrus* spp., which constitute the main components of the preparation. *Origanum vulgare* has been addressed in a vast body of literature and has been recognised for its natural potent antiparasitic properties. Essential oil of oregano reduces the incidence of bloody diarrhoea, reduces the number of faecal oocysts and prevents tissue damage (Giannenas et al. 2003; Anthony et al. 2005). It also improves feed conversion ratios and thus contributes to higher body weight gains (Bampidis et al. 2005). In addition, *O. vulgare* contains non-toxic compounds that have potent antimicrobial activities (Friedman et al. 2002; Anthony et al. 2005; Ichimori & Crump 2005). Oil of oregano demonstrates bactericidal activity at concentrations above 400 ppm, which is likely due to its high phenolic compound content (Marino et al. 2001; Friedman et al. 2002). The other component of the preparation under study, essential oil of *Citrus* spp., also exhibits strong antiparasitic properties. Studies by Abdelqader et al. (2012) highlighted a substantial effect of citrus essential oils with 96% limonene content against Ascaridia galli, which resulted in a 68.4% reduction in its invasion of experimentally challenged broiler chickens. The effectiveness of essential oils obtained from *Citrus* spp. is ascribed to its chemical composition, which is a highly complex natural mixture of various aldehydes, such as citronellal, citral, and others, with limonene being a dominant component. Limonene is the main constituent of citrus fruit peel and accounts for up to 95% of the total of orange peel oil, which is considered the richest source of monoterpenes (Lota et al. 2002).

The beneficial effects of *O. vulgare* and *Citrus* spp. on milk chemical composition, milk yield and other factors have been reported in numerous studies. Lacerda et al. (2014) demonstrated a positive influence of dietary oregano oil on milk quality. Volanis et al. (2004) and Bampidis and Robinson (2006) reported a positive impact of dietary *Citrus* spp. oil supplementation on milk composition. Therefore, the higher body weight and greater daily weight gain of lambs in the current study (Group 3) may be the result of improvements in dam milk yield and quality in response to constituents of the coccidiostat dietary supplement. Obviously, such changes in dam milk production were not only sole cause of the improved growth of lambs from Group 3. However, the coccidio- static activity of the dietary lambs supplement could substantially contribute towards these differences in growth. Junkuszew et al. (Junkuszew et al. 2015) demonstrated that decreasing the coccidian level increases lamb body weight and daily weight gains.

No clinical manifestations of coccidiosis (i.e. bloody diarrhoea) were observed in the flock in the current study, yet ongoing coccidiosis presented in a subclinical form. This information is quite valuable, as many sheep producers neglect coccidiosis in the absence of evident clinical signs. However, animals that are asymptomatic carriers of protozoan parasites can develop active coccidiosis and the presentation of clinical symptoms can be delayed until body condition has already become severely deteriorated (Binns et al. 2002). Consequently, ignoring subclinical coccidiosis without taking proper preventive measures can bring devastating economic loss to a sheep flock (Junkuszew et al. 2015).

The higher body weight and daily weight gain of lambs receiving the supplemented diet translated into improved carcase properties as indicated by *in vivo* evaluation. However, it should be noted that greater daily gains are frequently associated with the unfavourable increase in fatness (Carrasco et al. 2009). To determine the effect of the dietary supplement on adiposity and muscularity, *in vivo* ultrasound evaluation was performed (Miłerski 2001; Junkuszew & Ringdorfer 2005; Maxa et al. 2007; Grill et al. 2015). It was demonstrated that the dietary supplement containing the essential oil combination of *O. vulgare* and *Citrus* spp. had a positive influence on lamb muscularity while significantly lowering fatness. This result indicates that the dietary supplement contributes to meeting the demands of consumers for lean lamb as, in addition to pricing, lamb fat content is an important factor that is considered by consumers.

**Conclusions**

The inclusion of the preparation containing the essential oil blend of *O. vulgare* and *Citrus* spp. in the diet of sheep resulted in decreases in both the intensity and prevalence of coccidian infection within the flock as well had influence increases in lamb growth. Therefore, this dietary supplement may contribute to the improved profitability of sheep farming through...
increased production efficiency and the production of higher quality meat.

**Acknowledgements**

The authors thank Colin Cameron Ph.D. from ScienceDocs Inc. for language editing.

**Disclosure statement**

The authors declare that experimental procedures, interpretation of results or any scientific aspect of this study were not influenced by the product manufacturer. The authors alone are responsible for the content and writing of this article.

**References**

Abdelgader A, Qarallah B, Al-Ramamneh D, Das G. 2012. Anthelmintic effects of citrus peels ethanolic extracts against Ascaridia galli. Vet Parasitol. 188:78–84.

Anthony JP, Fyfe L, Smith H. 2005. Plant active components - a resource for antiparasitic agents? Trends Parasitol. 21:462–468.

Athanasiadou S, Kyriazakis I. 2004. Plant secondary metabolites: antiparasitic effects and their role in ruminant production systems. Proc Nutr Soc. 63:631–639.

Bampidis VA, Christodoulou V, Florou-Paneri P, Christaki E, Spais AB, Chatzopoulou PS. 2005. Effect of dietary dried oregano leaves supplementation on performance and carcass characteristics of growing lambs. Anim Feed Sci Tech. 121:285–295.

Bampidis VA, Robinson PH. 2006. Citrus by-products as ruminant feeds: a review. Anim Feed Sci Technol. 128:175–202.

Binns SH, Cox JI, Rizvi S, Green LE. 2002. Risk factors for lamb mortality on UK sheep farms. Prev Vet Med. 52:287–303.

Carrasco S, Ripoll G, Sanz A, Álvarez-Rodríguez J, Panea B, Revilla R, Joy M. 2009. Effect of feeding system on growth and carcass characteristics of ChurraTensina light lambs. Livest Sci. 121:56–63.

Chartier C, Padaud C. 2012. Coccidiosis due to Eimeria in sheep and goats, a review. Small Ruminant Res. 104:115–128.

Daugschies A, Agneessens J, Goossens L, Mengel H, Veys P. 2007. The effect of a metaphylactic treatment with dicyclazuril (Vecoxan1) on the oocyst excretion and growth performance of calves exposed to a natural Eimeria infection. Vet Parasitol. 149:199–206.

Dryden MW, Payne PA, Ridley R, Smith V. 2005. Comparison of common fecal flotation techniques for the recovery of parasite eggs and oocysts. Vet Ther. 6:15–28.

Friedman M, Henika PR, Mandrell RE. 2002. Bactericidal activities of plant essential oils and some of their isolated constituents against Campylobacter jejuni, Escherichia coli, Listeria monocytogenes, and Salmonella enterica. J Food Protect. 65:1545–1560.

Gauly M, Reej J, Bauer C, Erhardt G. 2004. Influence of production systems in lambs on the Eimeria oocyst output and weight gain. Small Ruminant Res. 55:159–167.

Geary TG, Conder GA, Bishop B. 2004. The changing landscape of antiparasitic drug discovery for veterinary medicine. Trends Parasitol. 20:449–455.

Giannenas I, Florou-Paneri P, Papazahariadou M, Christaki E, Botsoglou NA, Spais AB. 2003. Effect of dietary supplementation with oregano essential oil on performance of broilers after experimental infection with Eimeria tenella. Archiv Fur Tierernahrung. 57:99–106.

Grill L, Ringdorfer F, Baumung R, Fuerst-Waltl B. 2015. Evaluation of ultrasound scanning to predict carcass composition of Austrian meat sheep. Small Ruminant Res. 123:260–268.

Grzybek M, Kukula-Koch W, Strachecza A, Jaworska A, Phiri AM, Paleolog J, Tomczuk K. 2016. Evaluation of Anthelmintic Activity and Composition of Pumpkin (Cucurbita pepo L.) Seed Extracts—In Vitro and in Vivo Studies. Int J Mol Sci. 17:1456.

Hernández-Castellano LE, Moreno-Indias I, Morales-delaNuez A, Sánchez-Macias D, Torres A, Capote J, Argüello A, Castro N. 2015. The effect of milk source on body weight and immune status of lambs. Livest Sci. 175:70–76.

Ichimori K, Crump A. 2005. Pacific collaboration to eliminate lymphatic filariasis. Trends Parasitol. 21:441–444.

Junkuszew A, Milerski M, Bojar W, Szczepaniak K, Le Scouarnec J, Tomczuk K, Dudko P, Studzińska MB, Demkowska–Kutzapea M, Bracik K. 2015. Effect of various antiparasitic treatments on lamb growth and mortality. Small Ruminant Res. 123:305–312.

Junkuszew A, Ringdorfer F. 2005. Computer tomography and ultrasound measurement as methods for the prediction of the body composition of lambs. Small Ruminant Res. 56:121–125.

Kaplan RM. 2004. Drug resistance in nematodes of veterinary importance: a status report. Trends Parasitol. 20:477–481.

Klockiewicz M, Kaba J, Tomczuk K, Janicka E, Rypula K, Cencek T. 2013. Important: a status report. Trends Parasitol. 20:477–481.

Kochanowski M, Karamon J, Dabrowska J, Cencek T. 2013. Koprokopowe metody ilościowe w weterynaryjnej diagnoście parazytopologicznej - zastosowanie i problemy w szacowaniu ich skuteczności. Post Mikrobiol. 52:111–118.

Lacerda ECQ, Bauer LC, Oliveira JS, Silva FF, Carvalho SA, Macedo MS, de Souza NE, Simionato JI. 2014. Effect of the body composition of lambs. Small Ruminant Res. 56:121–125.

Le Sueur C, Mage C, Mundt HC. 2009. Efficacy of toltrazuril (Baycox® 5% suspension) in natural infections with pathogenic Eimeria spp. in Poland. Parasitol Res. 101:121–128.

Lacerta ECQ, Bauer LC, Oliveira JS, Silva FF, Carvalho SA, Macedo MS, de Souza NE, Simionato JI. 2014. Effect of the dietary inclusion of dried oregano (Origanum vulgare L.) on the characteristics of milk from Holstein × Zebu cows. Anim Feed Sci Techn. 192:101–105.

Mandal A, Prasad H, Roy R, Sharma N. 2007. Klopsekoopowe metody ilościowe w weterynaryjnej diagnoście parazytopologicznej - zastosowanie i problemy w szacowaniu ich skuteczności. Post Mikrobiol. 52:111–118.
from Lamiaceae and Compositae. Int J Food Microbiol. 67:187–195.
Maxa J, Norberg E, Berg P, Milerski M. 2007. Genetic parameters for body weight, longissimus muscle depth and fat depth for Suffolk sheep in the Czech Republic. Small Ruminant Res. 72:87–91.
Milerski M. 2001. In vivo assessment of meatiness and fattiness of Charollais ram-lambs. Czech J Anim Sci. 6:275–280.
Ndao M, Belot J, Zinsstag J, Pfister K. 1995. Épidémiologie des helminthoses gastro-intestinales des petits Ruminants dans la zone sylvo-pastorale au Sénégal. Vet Res. 26:132–139.
Perry BD, Randolph TF. 1999. Improving the assessment of the economic impact of parasitic diseases and of their control in production animals. Vet Parasitol. 84:145–168.
Prichard R. 1994. Anthelmintic resistance. Vet Parasitol. 54:259–268.
Raynaud JP. 1970. Etude de l’efficacité d’une technique de coproscopie quantitative pour le diagnostic de routine et le contrôle des infestations parasitaires des bovins, ovins, equines et porcins. Annales de Parasitologie (Paris). 45:321–342.
Stevenson M, Heuer C. 2012. Functions for analysing epidemiological data. Package ‘epiR’. EpiCentre, IVABS, Massey University, Palmerston North, New Zealand. 74.
Tomczuk K, Grzybek M, Szczepaniak K, Studzińska M, Demkowska-Kutrzepa M, Roczeń-Karczmarz M, Klockiewicz M. 2015. Analysis of intrinsic and extrinsic factors influencing the dynamics of bovine Eimeria spp. from central-eastern Poland. Vet Parasitol. 214:22–28.
Volanis M, Zoiopoulos P, Tzerakis K. 2004. Effects of feeding ensiled sliced oranges to lactating dairy sheep. Small Ruminant Res. 53:15–21.
Waller PJ. 1997. Sustainable helminth control of ruminants in developing countries. Vet Parasitol. 71:195–207.