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Animal health and greenhouse gas intensity: the paradox of periparturient parasitism

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ABSTRACT

Here we provide the first known direct measurements of pathogen challenge impacts on greenhouse gas production, yield and intensity. Twin-rearing ewes were ad libitum fed pelleted lucerne from day −32 to 36 (day 0 is parturition), and repeatedly infected with 10,000 *Teladorsagia circumcincta* infective larvae ($n = 16$), or sham-dosed with water ($n = 16$). A third group of 16 ewes were fed at 80% of uninfected ewes' feed intake during lactation. Methane emissions were measured in respiration chambers (day 30–36) whilst total tract apparent nutrient digestibility around day 28 informed calculated manure methane and nitrous oxide emissions estimates. Periparturient parasitism reduced feed intake (−9%) and litter weight gain (−7%) and doubled maternal body weight loss. Parasitism reduced daily enteric methane production by 10%, did not affect the methane yield per unit of dry matter intake but increased the yield per unit of digestible organic matter intake by 14%. Parasitism did not affect the daily calculated manure methane and nitrous oxide production, but increased the manure methane and nitrous oxide yields per unit of dry matter intake by 16% and 4%, respectively, and per unit of digestible organic matter intake by 46% and 31%, respectively. Accounting for increased lucerne input for delayed weaning and maternal body weight loss compensation, parasitism increased the calculated greenhouse gas intensity per kg of lamb weight gain for enteric methane (+11%), manure methane (+32%) and nitrous oxide (+30%). Supplemented with the global warming potential associated with production of pelleted lucerne, we demonstrated that parasitism increased calculated global warming potential per kg of lamb weight gain by 16%, which was similar to the measured impact of parasitism on the feed conversion ratio. Thus, arising from a pathogen-induced feed efficiency reduction and modified greenhouse gas emissions, we demonstrated that ovine periparturient parasitism increases greenhouse gas intensity. This implies that ewe worm control can not only improve production efficiency but also reduce the environmental footprint of sheep production systems.

1. Introduction

It is well recognized that pathogen exposure often results in anorexia, i.e. reduction in feed intake. In the case of sub-clinical gastrointestinal nematode parasitism, feed intake is typically reduced by up to 20–25% in, for example, growing and periparturient sheep, although wide ranges of parasitism-induced anorexia and associated production losses have been reported across different species (Sykes, 1994; Kyriazakis et al., 1998; Zaralis et al., 2008). Variation in feed intake can be expected to correlate with variation in greenhouse gas (GHG) production from both respiration and manure emission. This implies that pathogen challenge would be expected to result in reduced daily production of methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O), provided that the GHG yield, defined as the amount of GHG produced per unit of feed intake, is not affected. However, since pathogen challenge reduces productivity, arising from a combination of anorexia and reduced efficiency of resource use for production purposes (Sykes, 1994; Coop and Kyriazakis, 1999), challenged animals would be expected to take longer and require more resource input to achieve the same productive output. GHG production associated with this extra required resource input would effectively be the consequence of pathogen challenge on resource efficiency, and thus increase GHG intensity.

Here, we provide the first known direct assessment of the impact of pathogen challenge on GHG emission in livestock. We

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have assessed effects of gastrointestinal parasitism on performance, digestibility, CH_4 and CO_2 production and yield, and on feed efficiency, in lactating ewes. Furthermore, we used Intergovernmental Panel on Climate Change (IPCC) assumptions (Dong et al., 2006) and literature data where data were not derived from the experiment carried out, to extend the above to include estimates of manure CH_4 and N_2O production and yield. These estimates are used to test the hypothesis that periparturient parasitism increases ewe GHG intensity and global warming potential (GWP) for lamb production.

2. Materials and methods

2.1. Animals and housing

Twelve 4–5 year old Mule ewes (Bluefaced Leicester × Scottish Blackface) were recruited from each of four larger mating groups approximately 45 days before their observed mean parturition date (day 0), with the mean expected parturition dates separated by a week. Ewe body weight (BW) and body condition score (CS) were recorded on day −39 for the total of 48 ewes used and averaged (±S.E.) 68.2 ± 0.79 kg and 2.5 ± 0.06, respectively. Ewes were served by Suffolk rams and confirmed to be bearing twins by ultrasonic scanning prior to the experiment and were housed individually, in pens sized 1.30 m × 2.15 m with an adjacent creep area of the same size for their lambs. From day −45 to 30, the ewes were housed in a naturally ventilated and illuminated shed, with additional low-level lighting at night during lambing. From day 30 to 36, ewes and their lambs were housed in respiration chambers (see Section 2.2) in similar sized pens. Fresh wood shavings were used as bedding and added daily, and fresh water was available ad libitum. A small amount of shavings were also used daily in the respiration chambers.

2.2. Experimental treatments and feeding

The 12 ewes within each of the four mating groups were divided into three groups of four ewes based on initial BW, which resulted in three groups of 16 ewes with similar mean initial BW, CS and faecal egg counts (FECs). From day −45 to day −32, the ewes received ad libitum medium quality hay and approximately 300 g/day/head of a commercial ewe nut. From day −32 until day −25, allowances of hay and commercial ewe nuts were gradually reduced and completely replaced with increasing amounts of pelleted lucerne. From day −24 onwards, two groups of ewes were fed lucerne ad libitum and either remained uninfected (CON) or dosed with parasites (PAR). Details of the experimental infection are provided in Section 2.3. A third group of ewes was managed as CON ewes during pregnancy but fed restrictedly at 80% of intakes achieved by CON ewes during lactation (RES). The RES group was included to assess to what extent GHG production, yield and intensity would be affected by reduced feed intake per se. Ewes were fed at 0730 and 1500 h daily. The experiment was approved by, the Ethical Review Committee of Scotland's Rural College (SRUC), UK (ED AE 03/2011) and carried out under Home Office authorization (PPL 60/3782).

2.3. Experimental infection

Because the ewes were 4–5 year old and had previously grazed natural pastures infested predominantly with *Teladorsagia circumcincta*, they were expected to have had substantial prior exposure to this parasite, an abomasal nematode of particular concern in temperate regions. The ewes were orally treated on day −38 with levamisole (Levacide, Norbrook, Newry, UK) and ivermectin (Oramec, Merial, Harlow, UK) at the rate of 7.5 and 0.2 mg/kg of BW, respectively, to remove worm burdens. A subsequent FEC taken on day −22 averaged 0 (0–1) eggs per g of fresh faeces (epg), suggesting that the drench was effective. The PAR ewes were then trickle infected with 10,000 infective *T. circumcincta*, suspended in 10 ml of water and administered every Monday, Wednesday and Friday from day −21 onwards until the end of the experiment. The CON and RES ewes were sham-infected with 10 ml of water on the same days. The *T. circumcincta* strain used was the Moredun Ovine Susceptible Isolate that has been maintained in the laboratory for several years. This infection model has repeatedly been used in our laboratory to induce sub-clinical parasitism in periparturient ewes (Houdijk et al., 2003; 2006; Zaralis et al., 2009; Kidane et al., 2010).

2.4. Measurements and calculations

2.4.1. Performance

The ewes were weighed on day −39 and then weekly from day −31 onwards, as well as within 12 h of parturition to assess daily weight gain during late pregnancy and during lactation through linear regression of BW over time. The lambs were weighed within 12 h after birth and weekly afterwards to assess daily litter weight gain in the same way. Since the lambs did not receive creep feed, lamb BW and daily weight gain were used to calculate milk production (Robinson et al., 1969). Ewe CS was taken approximately fortnightly, by lumbar palpation on a zero to five point scale, and to an accuracy of one-quarter (Russel et al., 1969), where 0 is emaciated and 5 is obese. Feed samples were collected every day during the experiment at the time of feeding and were pooled for chemical analyses (Table 1) as per standard protocols (Ministry of Agriculture Fisheries and Food, 1992). Feed refusals were recorded twice weekly (Mon and Thu) and analysed for dry matter (DM) only. This allowed the calculation of achieved mean daily dry matter intake (DMI).

2.4.2. Parasitism

The level of parasitism was monitored through regular faecal sampling for FECs, according to a modified flotation method (Christie and Jackson, 1982), with a sensitivity of one epg. This was done for all ewes at housing, day −22, day −11, and at parturition, and then weekly thereafter (for PAR ewes only).

2.4.3. Digestibility

Apparent total tract DM, organic matter (OM) and nitrogen (N) digestibility were assessed through using acid insoluble ash (AIA) as an internal, indigestible marker. Feed samples collected daily during feeding were pooled for DM, N, ash and AIA analyses, with

Table 1
Analysed composition of the lucerne used.

Analysis	
Dry matter (DM, g/kg)	974
Neutral detergent fibre (g/kg DM)	448
Acid detergent fibre (g/kg DM)	362
Crude protein (6.25 × N, g/kg DM)	163
Ash (g/kg DM)	103
Acid hydrolysis ether extract (AH-EE, g/kg DM)	19.4
Acid insoluble ash (g/kg DM)	13.7
In vitro organic matter digestibility (NCGD[a], %)	57.2
Gross energy (MJ/kg DM)	17.9
Digestible energy[b] (MJ/kg DM)	10.2
Metabolizable energy[c] (MJ/kg DM)	8.3

[a] Neutral cellulose and gammanase digestibility.
[b] Calculated as metabolizable energy (ME)/0.81 (AFRC, 1993).
[c] Calculated from AH-EE and NCGD (Thomas et al., 1988).